# Metamorphoses: seventeenth-century ideas on fossils and Earth history

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A thesis submitted to fulfil requirements for the degree of Doctor of Philosophy.

This is to certify that, to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

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**Abstract**

*Metamorphoses* is broadly about how fossils regained their historicity in the seventeenth century, and how this changed history as fossils were simultaneously transformed into instruments of science in the hands, hearts, and minds of savants of the organic origin opinion - the opinion that fossils are either the petrified remains of once-living beings themselves, or their imprints. In studying the past with fossils, intertwined sacred, civil and natural histories became hypothetical, subjected to new, instrument-mediated investigative methods; in turn, fossils were investigated historically; and novel epistemological practices – outcomes of ontological anxieties – produced historicities, and a common experience of Earth history.

More specifically, *Metamorphoses* examines the work of Robert Hooke, John Ray, Nicolaus Steno, Thomas Burnet, William Dugdale, Bernardino Ramazzini, Gottfried Wilhelm Leibniz, and others, to discuss how and why they broke from traditional history in idiosyncratic yet overlapping ways. Their shared idea about what a fossil is fostered a shift in visuality belonging to the seventeenth century with its instrument-mediated vision, and novel investigative methods; but it also represented their new attitudes to history, for interest in fossils was not only about phenomena. Rather, by amalgamating new ways of observing and imagining the earth with ancient wisdom, alchemical ideas, and humanist textual practices, these Earth historians fashioned historiographical approaches that could scarcely have been imagined a century before. Leibniz's struggle to make a scientific history, by mixing helpings of the work of Burnet, Ramazzini, and others into his own ideas handed new tools to eighteenth-century historians, not only tools for doing and thinking about Earth history but also tools for witnessing and understanding its metamorphoses.

'… the first law of history is to dare to say nothing false, and again to omit nothing which is true' (Cicero, *De Oratore*).

## Contents

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# CHAPTER 1: INTRODUCTION

An early glimpse of the historiographical and historical problems and changes particular to the seventeenth century was captured by the Flemish painter of curiosity cabinets Frans Francken the Younger in his *A Collector's Cabinet* of 1617 (Figure 1). Although much can be (and has been) interpreted from Francken's deliberate composition and layering – especially when taking into consideration the relationship between the arts, sciences, and histories contained in the cabinet versus the donkey-headed iconoclasts in the background outside – we will use this painting as a prompt with which to start pondering the hotchpotch of seventeenth-century historicities (authentic histories). In general, there were three – as the collection in Francken's cabinet reveals. In the fore- and middle-grounds of the painting, on the table and wall

*Figure 1: Frans Francken the Younger,* The Collector's Cabinet, *1617. A magnifiable version is available online at https://www.rct.uk/collection/405781/the-cabinet-of-a-collector (accessed 16 September 2020).*

respectively, representations and objects of sacred, civil, and natural histories have been assembled for display in a manner suggestive of crammed disarray. For instance, in a painting leaning back against the wall on the left-hand side of the table, Mary and Joseph flee to Egypt with Jesus near a bowl of modern coinage, sitting closer to the middle, around which traditionally antiquarian objects lie scattered: ancient Roman coins, possibly also a Roman sepulchral lamp, sea heart beans and nickar nuts, seashells and fossilised shark teeth (glossopetrae). A bundle of letters in the foreground, one unfolded in a manner to show that it arrived locked, indicates perhaps that the owner of these curiosities was an intellectual involved in the Republic of Letters.[1]

We will discuss all three histories in the chapters that follow, for they are as inseparable as in the cabinet, but our focus will be new (as well as new-old – to be explained shortly) ideas and changes to the history of the earth, so let us concentrate a little more closely on the glossopetrae (one lies visible on the lower right-hand corner of the table, the other rests to the left of the unlocked letter just off centre on the table's edge). Early modern experimentalists, natural philosophers and naturalists, antiquarians, and others, were digging up these strange and mysterious objects not only out of the rock and sand of beaches but also out of mines and mountaintops, along with other objects of stone, many of which resembled complete marine creatures such as the snake-stones nowadays known as ammonites. Were these dug-up objects perceived or thought about as historical? For most seventeenth-century writers of history, the answer was no, and this makes them interesting because the few who did see and think of fossils as historical objects would change our

[1] For the flight to Egypt, see Matthew, 2:13–23. For further details on the painting, see CWLF: White, C., 2007. Author unknown, *The Later Flemish Pictures in the Collection of Her Majesty the Queen* – CWLF 32 (https://www.rct.uk/collection/405781/the-cabinet-of-a-collector, accessed 16 September, 2020). For the identification of the sea heart and nickar, see Gerhard Cornelis Cadée, 'Sea heart and nickar nuts in a Flemish painting of 1617', royal Netherlands Institute for Sea Research (NIOZ), DOI: 10.3366/anh.2011.0041. For the Republic of Letters, within the context of Earth history, see Rhoda Rappaport, *When Geologists were Historians* (Ithaca: Cornell University Press, 1997). For early modern letter locking, see Jana Dambrogio, Daniel Starza Smith, and Massachusetts Institue of Technology (MIT) Unlocking History Research Group at letterlocking.org; also see their wonderful YouTube channel, https://www.youtube.com/@Letterlocking, accessed 9/7/2018.

understanding and experience of the history of Earth.

Indeed, it is well-established that, in the seventeenth century, the proponents of two equally extreme fossil ontologies competed for the right to make authoritative claims on the history of the earth (though it needs to be noted that the word "fossil" had a more general meaning, defining anything dug up).[2] On the one hand was the new and popular idea that fossils were the products of *lusus naturae* or nature's games, generated by a plastic virtue in the earth that sculpted stone into the appearance of a marine creature, inside and from the stone (*lapides sui generis*) in which the 'cockle-stone' was dug up. This was a popular opinion, especially in England. It was developed to explain away why marine fossils or 'cockle-stones' were found on mountains as high as the Alps as well as in mines, as an apologia for the assumption that the earth's superficies had changed negligibly since Creation.[3] On the other hand was a new-old idea: the ancients *had* thought of fossils as historical, that is, as objects of organic origin – either the petrified remains of once-living beings or their imprints.[4] That is, fossils were not nature's mimesis but the past *re*-presented – made tangibly present. This ancient, organic origin opinion was adopted and promoted by several early modern savants, and only it allowed

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[2] For words not explicitly defined by the author of a primary source, I rely on various seventeenth- and eighteenth-century dictionaries for the definition of words that may be confused with current descriptive definitions; for example, Robert Crawdrey, *A Table Alphabeticall* (London, 1604), John Kersey, *Dictionarium Anglo-Britannicum* (London, 1708), Thomas Dyche, *A New General English Dictionary* (London, 1760 [1709]).

[3] John Woodward, *An Essay towards a Natural History of the Earth, and Terrestrial Bodyes, especialy Minerals* (London, 1695), 40-41. For secondary sources, see Martin Rudwick, *The Meaning of Fossils* (Chicago: University of Chicago Press, 1985); Rhoda Rappaport, *When Geologists were Historians* (Ithaca: Cornell University Press, 1997); and Paolo Rossi's excellent *The Dark Abyss of Time*, English'd by Lydia G Cochrane (Chicago: University of Chicago Press, 1984).

[4] For primary sources see, Robert Hooke, *Discourse of Earthquakes*, in Robert Hooke, *The Posthumous Works* (London, 1705), 407, 411; Woodward, *An Essay towards a Natural History of the Earth*, 40-41; Nicolaus Steno, *The Prodromus to a Dissertation Concerning Solids Naturally Contained within Solids* [*henceforth Prodromus*], English'd by Henry Oldenburg (Little Britain, 1671), 10-11. For secondary sources see, William Poole, *The World Makers* (Oxford: Peter Lang Ltd, 2010), 116, 130-132. Also see Rappaport, who mentions that the lusus naturae idea is a Neo-Platonic one, in Rappaport, *When Geologists were Historians*, 106-107; however, note that to claim that an idea has roots in antiquity is not the same thing as to claim that it is an ontology from antiquity. Roger Ariew has shown that the organic origins classical ontology was also the 'standard scholastic doctrine', in Roger Ariew, 'Leibniz and the Petrifying Virtue of the Place', 33-54, in Koen Vermeir and Jonathan Regier (eds), *Boundaries, Extents and Circulations: Space and Spatiality in Early Modern Natural Philosophy* (Switzerland: Springer, 2016), 36, 35-37.

for an image of nature 'no longer opposed ... to history,' as put by Paolo Rossi, 'which is the reign of becoming and change.'

*Metamorphoses* is about how fossils regained their historicity; it is about how this changed history as fossils were simultaneously transformed into instruments of science in the hands, hearts, and minds of early moderns of the organic origin opinion. In studying the past with fossils, intertwined sacred, civil and natural histories became hypothetical, subjected to instrument-mediated investigative procedures; in turn, fossils were investigated historically; and new epistemological practices – outcomes of ontological anxieties – produced historicities. Robert Hooke (1635–1703), with whom we will begin, and his contemporaries, operated in a similar intellectual environment to that of Francken's cabinet; however, they were all on a quest to find, or to create, order in the chaos of new objects, and the histories of Earth that these objects supported. For Hooke, a follower of Francis Bacon's, ideas on how to order nature had roots in Bacon's edicts on knowledge and education. Bacon, who published both his *Great Instauration* and *New Method* in 1620 – just three years after *A Collector's Cabinet* – was cosily ensconced in the cabinet culture represented by Francken's painting. But Bacon expresses enthusiasm, even earlier in 1594/1595, for the intellectual gains that such a space of accumulated and collected potential could provide:

> *[a] goodly huge Cabinet, wherein whatsoever the Hand of Man, by exquisite Art or Engine, hath made rare in Stuff, Form, or Motion, whatsoever Singularity, Chance and the Shuffle of things hath produced, whatsoever Nature hath wrought in things that want Life, and may be kept, shall be sorted and included.*[5]

Although Bacon was buried six years before Hooke was birthed, Hooke

[5] Francis Bacon, 'The Second Councellor advising the Study of Philosophy', in *Gesta Grayorum (1914 [1688])*, 35. Note that the attribution to Bacon is based on an examination of internal evidence by James Spedding, in *Letters and Life of Francis Bacon* (1861), i.325, as explained in the 1914 reprint of the 1688 publication of the *Gesta* by the editor W W Greg on page vi. The lines cited by me, in context of their place in the *Gesta*, and an intertextual analysis, bear more than a striking resemblance to lines from Francis Bacon, *The New Atlantis,* in Francis Bacon, and James Spedding, Robert Leslie and Douglas Denon Heath (eds), *The Works of Francis Bacon, Volume 3* (Cambridge: Cambridge University Press, 2011 [1857]), 119–166.

considered him his mentor, and took upon himself the responsibility of actualising Bacon's plans for an instauration of knowledge, including the cabinet, which became the 'Repository' of the Royal Society of London.

Hooke wishes for a 'Repository … of all varieties of Natural Bodies as could be obtain'd', not for gazing at in wonder – which according to him is what curiosity cabinets are usually used for – but for 'the most serious and diligent study of the most able and Proficient in Natural Philosophy'.[6] Notice, however, that unlike Bacon's description above, Hooke's cabinet contains only 'Natural Bodies', not artificial ones; natural bodies with which he, 'able and Proficient',

> might peruse, and turn over, and spell, and read the Book of Nature, and observe the Orthooraphy, Etymologia, Syntaxis, and Prosodie of Natures Grammar, and by which, as with a Dictionary, he might readily turn to find the true Sentences of Nature written with indelible, and most exact, and most expressive Letters.[7]

The ancient "Book of Nature" trope was well-worn by Hooke's time, but this was not simply an attempt to use an ancient and ubiquitous trope; rather, it was, as put by Karen Edwards, 'a way of reconciling the very different attitudes of the natural world', a way to '*renovate* the old learning by accommodating it to the new'.[8] For Hooke, following Bacon, this necessitated eschewing imagined emblems enforced upon surface appearances as self-evident truths, instead making internal observations of the structural parts and similarities of natural objects to re-learn nature's language.[9] That is, when coming from Hooke's mouth, tired terms gain a new meaning: his second wish follows his first, and narrows down to the nitty-gritty natural bodies that he has

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6 Robert Hooke, *Discourse of Earthquakes*, in Robert Hooke and Richard Waller (ed), *The Posthumous Works of Robert Hooke* (London, 1705), 285, 338. For the Royal Society repository, see Michael Hunter, 'Between Cabinet of Curiosities and Research Collection: The History of the Royal Society's Repository', in Michael Hunter (ed) *Establishing the New Science* (Woodbridge: Boydel, 1989), 123–155.

7 Hooke, *Discourse of Earthquakes*, in Robert Hooke and Richard Waller (ed), *The Posthumous Works of Robert Hooke*, 338.

8 Karen L Edwards, *Milton and the Natural World: Science and Poetry in Paradise Lost* (Cambridge and New York: Cambridge University Press, 1999), 41.

9 For this idea broadly and generally expressed, see James J Bono, *The Word of God and the Languages of Man: Interpreting Nature in Early Modern Science and Medicine* (I) (Wisconsin, USA: The University of Wisconsin Press, 1995), 14–15.

in mind, for only one kind of body painted in *A Collector's Cabinet* captures Hooke's historical imagination with respect to Earth's history, and in so doing, reveals how he thinks nature's book ought to be read and why: 'I could heartily wish that a Collection were made in this Repository of as many varieties as could be procured … of Fossile-Shelles and Petrifactions'. These are the 'indelible, and most exact, and most expressive Letters' with which nature writes 'true Sentences' – her, as mentioned, characteristic marks – observed and "read" by Hooke with his microscopes, the minute minutiae recorded by his drawings.[10]

However, Hooke was far from the only seventeenth-century intellectual to employ optical instruments, whether literally or figuratively, for the study of Earth history. Others – such as John Ray, Thomas Burnet, William Dugdale, Nicolaus Steno, Bernardino Ramazzini, and Gottfried Wilhelm Leibniz – just as excited by the 'new visible World …. under our feet' as well as the potential for new discoveries about its history, also relied upon instrument-mediated vision and instrument-mediated imagination when peering into the murky depths of the earth's past. Their historiographical methods and visualisations of Earth history, which are seemingly disparate, were shaped by the changing culture of seventeenth-century natural history and natural philosophy, creating a collective seventeenth-century experience of Earth history.

This culture was shaped *not* by a rupture of the new from what came before, but from mixtures and reactions of ancient wisdom with modern ideas, imagination, and practices. For this reason, I use the term 'Earth history' throughout *Metamorphoses* instead of 'natural history', because although Burnet (for example) writes of 'natural history', its meaning *for him* has changed. Moreover, according to Phillip Sloan, traditional natural history, with roots in classical antiquity, was 'a collection of reports on all topics, particularly those of detail about natural objects', an 'empirical database' of facts, which once collected were not used to seek a 'causal understanding through

[10] Hooke, *Discourse of Earthquakes*, 338.

philosophical events'.[11] In other words, traditional natural history, tasked with describing qualitative properties, studied how things were found in nature instead of how they came to be that way. Pliny the Elder's *Natural History* is an example of this tradition, and was still cited as an authoritative text in the seventeenth century. But a similar schism (between natural versus Earth history) occurred in the closely related antiquarian tradition. As argued by Daniel Woolf, antiquaries traditionally placed primacy on space over time in their surveys and records, taking care to document artificial spatial boundaries of cultural significance like marker stones and consecrated land. Woolf notes that texts like William Dugdale's *Antiquities of Warwickshire* (1656) blurred these boundaries as well as the antiquarian genre by incorporating broad history into local and familial accounts, and in doing so, placed importance on chronology and events over space. Dugdale, for example, did this not only by using sacred and civil history in support of local accounts, but also by studying, sometimes first-hand, changes to the earth's superficies. (Like Hooke and others, I use the seventeenth-century term 'superficies' instead of 'surface', because 'super-ficies' implies that there are sub-faces, or strata, which were all a surface once upon a time, providing evidence of a physical, horizontal history of the earth.) This treatment placed a new importance on chronicling causes and effects—again, on how a place came to be instead of simply how it was found. In contrast to Dugdale, Robert Plot continued to produce traditional natural histories well towards the close of the century – an example being his 1677 *The Natural History of Oxford-shire*, in which he disparaged Hooke's work on fossils.[12] Thus I use 'Earth history' to mean an examination of physical and spatial changes through time of interrelated events: events that occur causally hence historically.

When the intellectual challenges of this instrument-mediated empiricism

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[11] Phillip R Sloan, 'Natural History, 1670–1802', in R C Olby et al., (eds), *Companion to the History of Modern Science* (London: Routledge, 1990), 295-296; also see Karen Edwards, in *Milton and the Natural World*, 5.

[12] Daniel Woolf, *'Horizons of early modern historical culture'*, in D R Kelley and D H Sacks (eds), *The Historical Imagination in Early Modern Britain* (Cambridge: Cambridge University Press, 1997),106–111, fn. 40.

are considered within context, things previously portrayed by scholars as baroque extravagances can be re-examined as serious attempts by early modern savants to understand their novel world – a world opened and expanded by optical instruments such as the telescope and the microscope.[13] As put by Ofer Gal and Raz Chen-Morris, 'the Baroque obsession with details' becomes a 'sincere attempt to come to terms with the overwhelming variety of new objects';[14] not only in art but also in objects of science and history disinterred from the earth, whether natural, such as fossils, ores and even whole trees, or products of human art. Similarly, the new science transformed the historical imagination, creating a shared thus common seventeenth-century experience of history.

Chapter Two, *Groundwork*, introduces the beginnings of Hooke's fossils investigations, and his concept that characteristic marks can be identified by microscopically examining the internal structure of a fossil and comparing it to similar living kinds, such as trees and marine creatures. Hooke picks up the notion of characteristics from Francis Bacon, specifically Bacon's ideas for a sanitised alchemy;[15] that is, an alchemy built upon foundations of Bacon's histories, not on signs or signatures, and their correspondences. The close relationship between alchemy and fossils stems from the belief that petrifaction is nature's transmutation: whereas traditional alchemy attempts to transmute one metal into another, petrifaction transmutes an organism into a stone. Natural transmutation is therefore superior to artificial, because metals are of the same species, whereas nature transmutes one genus into another. Thus, alchemists were making conjectures on how things petrify, at least one of which plays a fundamental part in the development of Hooke's ideas on fossils.

Chapter Three, *Snake-Shells*, continues the analysis of Hooke's fossil trials, moving from plants to animals – specifically his representations of snake-stones

[13] Ofer Gal and Raz Chen-Morris, *Baroque Science* (Chicago, USA: University of Chicago Press, 2013), 10–11.
[14] Gal and Chen-Morris, *Baroque Science*, 11.
[15] The term 'sanitised alchemy' is, to the best of my current knowledge, Paula Findlen's. See: Paula Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', in Donald R Kelley (ed), *History and the Disciplines: the Reclassification of Knowledge in Early Modern Europe* (Rochester, 1997), 239–260.

or ammonites – and introduces the topic of how the visual representation of fossils figures into historicity. His challenge where external appearances are concerned is to shift his audience's perception from seeing stones that mimic cockles to seeing cockles that turned into stone – either the petrified remains of marine creatures themselves or their imprints. Hooke attempts to order and present his examinations and visual descriptions of the external parts of petrified bodies in such a way that changes the process by which his readers interpret what they are observing, inducing a similar shift in perception to the one experienced by a moving viewer looking at an anamorphic illusion and suddenly stepping into a privileged vantage point that restores the distorted picture's perspective.

Chapter Four, '*from a different view of Nature*', expands the topic of representation by analysing the work of Martin Lister in conjunction with his friend John Ray's, to show how different visualities create divergent historicities even when examining the same physical evidence. In a 1671 critical review of Steno's *Prodromus,* Lister declared that fossils are '*Lapides sui generis*'. Lister has 'a different view of Nature' – a different visuality owing to his specific way of observing the natural world, which is modified by and reflects his developing practices as a naturalist.[16] His 'different view' is revealed by his preferred practical approach to solving a problem, and the similes and metaphors that he employs while describing actions and things. Yet Ray's postscripts of opposing observations of the same fossils, appended to Lister's published letters and critiques, allow for dual voices on conflicting concepts of visual meaning to coexist, thereby underscoring, by juxtaposition, the complicated processes and relations involved in producing them.[17]

Chapter Five, '*very deficient in Natural History*', takes a turn to history proper, examining how Hooke employs myths in a measured, methodical discussion about history and memory, and establishes criteria which he uses to

[16] Martin Lister, *A Letter … Adding Some Notes upon … Steno Concerning Petrify'd Shell* [henceforth *A Letter*], in *Royal Society Philosophical Transactions*, Vol. 6 (London, 1671), 2282.

[17] For Lister's transcription of Ray's remarks, in his letter to Oldenburg on star-stones, see Martin Lister, in A Rupert Hall and Marmi Boas Hall (eds and trans), *The Correspondence of Henry Oldenburg*, Vol. 10 (Madison, USA: University of Wisconsin Press, 1965–), 562–563.

form relations between myth and civil history parallel to the relations between fossils and Earth history. In using a mixture of myth and ancient history as testimony to 'Metamorphoses', from which my work takes its title, and translocations, Hooke faces two challenges. The first is a problem of chronology and time, owing to alternative timescales in ancient texts which contradict biblical chronology. The second problem, which Hooke struggles to surmount, is to convince his critics that his chosen sources are not poetic fables, but reliable, 'true Histories'.[18]

By contrasting the observations of Lister's friend Robert Plot's objections to Hooke's ideas on the organic origin of fossils, and extinction, as well as Plot's and Hooke's use of civil, sacred and natural histories, I show that Plot and others of the *lapides sui generis* persuasion represent fossils as static resemblances – nature's mimesis – generated in an earthly surface that has undergone negligible change since Creation. Whereas for Hooke, fossils are *re*-presentations. Hooke's observations, experiments and attempts to construct a theoretical framework based on spatial and temporal considerations – thus, history – by studying fossils not as objects of mimesis but as *traces* of the earth's changes provide support for his concept that the key to understanding variety and order rests in motion.[19] In this new practice of observation, fossils are paradoxically a synecdoche of nature's diversity and dynamics, which can be used to construct a history of the earth from the earth.

Chapter Six, 'so utterly extinct and gone', reveals how instrument-mediated vision changed how Earth history was imagined, experienced, and understood in a new way. I argue that the historical ideas in Thomas Burnet's *Sacred Theory of the Earth* were imagined and composed *as if* viewing the earth and its past with optical instruments. Burnet concluded that we live on ruins, and that the earth is decaying – an idea shared by Hooke (and others), as part of his ideas on the earth's aging body. This idea that the earth is a senescing body was crucial to the development of a seventeenth-century

[18] Hooke, *Discourse of Earthquakes*, 406.

[19] Ofer Gal, 'Nature's Grammar', *Stud. Hist. Phil. Sci.,* Vol. 30, No. 3, pp. 501-510. Great Britain: Elsiever Science Ltd, 1999, 501-02. Rossi, *The Dark Abyss of Time*.

Earth history because it allowed thinking of Earth as undergoing change. However, both Burnet's and Hooke's ideas continued to raise Ray's anxiety levels. For Ray, it thus became necessary to present the earth's senescence as part of the principle of providence. Comparing the work of Hooke and Ray shows how the same theoretical and practical tools, heavily reliant on the imagination and the re-drawing of its limits, were used to quell or enhance epistemological anxieties.

Chapter Seven 'A Solid Body Enclosed by Process of Nature within a Solid', widens our view from England to the Continent, and to Nicolaus Steno's *Prodromus*, comparing his representations of fossils and Earth history with Hooke's. As pointed out by Henry Oldenburg in his translation of the work, Steno's ideas bear more than a passing resemblance to Hooke's. Further, both Hooke and Steno manipulate and order the earth's superficies in theory just as it is manipulated in practice by human hands and art. So, it is important to consider how expert knowledge in one field contributes to the creation of meaning, and to the clarification and obfuscation of understanding, when applied to another. For example, Steno transfers his anatomical knowledge to his studies of the earth's senescing body, comparing fluids and solids in the human body to the earth's fluids and solids. It is in this chapter, therefore, where changes to Aristotle's as well as Aristotelian ideas on the formation of metals and minerals are explored in a little more depth.

Paralleling Hooke and Steno reveals that their divergent ways of subjecting history to the investigative procedures of the new science nevertheless create convergent fossil ontologies, and notions on how nature works, in turn altering historical approaches to the study of the earth's superficies. Whereas Steno is content to restrain his investigations to the earth and to answer the problem of petrified bodies and place, Hooke's ambitions take into account all earth-like planets – such as the moon – their parts, wholes, motions and relations. Meantime, Steno's use of Stoic natural philosophy and rhetoric for the development of what he considers to be an ethical physics (and therefore Earth study) is a sincere attempt to make this new history, as well as its novel investigative practices and instruments, common to all.

Chapter 8, 'the history of changes', further examines how poetry (imagination) is necessary to fill history's gaps. The claim was first made by Bacon, who believed that historicising both alchemical language and practices could take man and Earth back to their Edenic states, an idea embraced by Hooke, which also appears in the thought and work of Steno and others – such as Gottfried Wilhelm Leibniz.

Poetry was vital to the development of Leibniz's ideas on Earth history, and his historicist metaphysics, which would resonate through the eighteenth century, as revealed by Chapter 9, *Protogaea*. Leibniz's *Protogaea* represents the culmination of ideas discussed in previous chapters, because Leibniz uses Burnet's philosophical poetry, Bernardino Ramazzini's empirical approach, and Steno's and Hooke's work as resources with which to develop a science of history, which I conclude with in Chapter 10.

By now, the reader may have noticed the lack of a literature review. This is because the subject matter of seventeenth-century fossils and Earth history encompasses many different disciplines – from art, alchemy, and the antiquarian tradition, through anatomy and mining to traditional natural history and physico-theology, to name but a few – which would have appeared disjointed in a traditional literature review. Therefore, a literature review, relevant to the subject matter being discussed, is woven into the start of the chapters or sections, with further commentary and recommended reading, if necessary, to be found in the footnotes.

# CHAPTER 2: GROUNDWORK

On the 1st of February 1674, Robert Hooke spent his Sunday 'At home till 6 writing history etc. At Garways. Drank 4 dishes of coffee. Slept not all night.'[20] The history that most fascinated Hooke was the earth's: its natural changes through time. And when he scribbled the above words into his diary, both 'writing history' and Earth history were changing in ways that would have been unimaginable just decades before, namely, before the invention of instruments such as the microscope and telescope. As put by Hooke, '*by the help of* Microscopes, *there is nothing so* small, *as to escape our inquiry; hence there is a new visible World discovered to the understanding … By this the Earth it self, which lyes so neer us, under our feet, shews quite a new thing to us*'.[21] New, instrument-mediated vision of the seventeenth century was altering practices of experimental observation, making the invisible visible, and creating new objects of science and with them new conceptions – for example, Hooke's fossils. It was also affecting the experience of history, with optical instruments expanding the imagination by broadening the limits of vision, and fossils providing a novel glimpse of a 'new visible World' in the earth's past.

In January of 1665, six months before Hooke was forced to leave London, fleeing from what would become known as the Great Plague, he published his acclaimed *Micrographia*. Here, for the first time, Hooke publicised his answer to the question of what 'Fossile-Shelles and Petrifactions' or 'Petrify'd Bodies' are (as mentioned, in the seventeenth century, the word "fossil" had a more general meaning, referring to anything dug up).[22] According to him, fossils were not nature's games (*lusus naturae*), nor were they made of the stone from which they were dug up. Martin Lister, the Royal Society's arachnologist, conchologist, and mineralogist, and his friend Robert Plot, a naturalist and the

[20] Robert Hooke, Henry W Robinson, and Walter Adams (eds), *The Diary of Robert Hooke, MA, MD, FRS,1672–1680* (London: Taylor and Francis, 1935), 86.

[21] Robert Hooke, *Micrographia* (London, 1665), 'Preface', unpaginated.

[22] Robert Hooke, and Richard Waller (ed), *The Posthumous Works* (London: Sam Smith and Benjamin Walford, 1705), 338.

first keeper of the Ashmolean Museum, defended the ad hoc explanation that the earth generates organic forms in stone due to nature's overabundance of generative force for those particular forms.[23] Hooke, instead, adopted an Aristotelian idea: fossils were either the remains of organisms, or their imprints, and therefore evidence that the earth's surface *had* changed significantly since Creation.[24] To borrow from Lister, these differing opinions on what fossils are originate 'from a different view of Nature'.[25] Hooke's view was perhaps the most extreme of all, for unlike most of his peers – whether of the organic origin or stony persuasion – Hooke maintained that those stones had not only been organisms but also that they were extinct. Thus, fossils and petrifaction were important topics because the proponents of two opinions on what fossils are were competing for the right to make authoritative claims on Earth history.

Fossils, petrified animal or vegetable matter, Hooke claims, have been found, 'by several sorts of trials' to be of organic origin ('to be truly so'):

> not only in External Figure, but also in the Internal and Substantial Parts of them; so that in truth there is no manner of Reason to doubt them to be of those very Substances they so perfectly and fully resemble.[26]

Hooke's challenge was to convince his audience that the similitude of a fossil form to that of a marine creature (for example, the nautilus – his favourite) indicated a clear relationship of not resemblance but representation. That is, the fossil was either *present* again or *re*-presented by its imprint.[27] To support this ontology of fossils, Hooke showcased the development of a new way to

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[23] Lister, *A Letter*. Also see Aaron Garrett (ed), *The Routledge Companion to Eighteenth Century Philosophy* (London, UK: Routledge, 2014), 720.

[24] For primary sources, see Robert Hooke, *The Posthumous Works*, 407, 411; John Woodward, *An Essay towards a Natural History of the* Earth (London, 1695), 40–41. For secondary sources, see William Poole, *The World Makers: Scientists of the Restoration and the Search for the Origins of the Earth* (Oxford: Peter Lang, 2010), 116, 130–132. Also see Rhoda Rappaport, who mentions that the *lusus naturae* idea is a Neo-Platonic one, in Rappaport, *When Geologists were Historians*, 106–107. Roger Ariew has shown that the organic origins classical ontology was also the 'standard scholastic doctrine', in Roger Ariew, 'Leibniz and the Petrifying Virtue of the Place', 33–54, in Koen Vermeir and Jonathan Regier (eds), *Boundaries, Extents and Circulations: Space and Spatiality in Early Modern Natural Philosophy* (Switzerland: Springer, 2016), 36, 35–37.

[25] Lister, *A Letter*, 2282.

[26] Hooke, *Discourse of Earthquakes*, 338.

[27] Gal, 'Nature's Grammar', 502-3.

identify the origin of petrified things such as woods and shellfish: by disclosing internal, microscopic, 'characteristick marks'.[28] He argued that unlike external appearances, these marks were not accidents; that, being microscopic and internal, they could not be counterfeited artificially; and that they could be used for the study of Earth history. These were ideas that Hooke was forced to defend.

According to Charles Lyell, in Volume I of *The Principles of Geology* (1880), Hooke was first to promote and publicise a history of the earth based on changes *of* the earth ('between geological phenomena and earthquakes') rather than stories about human populous changes over space and time.[29] Indeed, Hooke wished to know and to tell the history of Earth *from Earth itself* rather than from civil or sacred histories; and as the curator of experiments for the Royal Society of London, he had an active hand in twisting the course of the earth's story with his new microscopic approach to the study of fossils. After his first explanation of the phenomenon of petrifaction in his famous *Micrographia* of 1665, Hooke repeated, reinforced, and refined his ideas in his first *Discourse of Earthquakes* lectures of 1667 and 1668. Indeed, over the course of his career, Hooke repeated himself, revised and defended his causal account of how marine fossils came to be on mountaintops as well as in the deepest pits of mines, to support his claims on earthquakes. By the time of his final incendiary *Discourse* lecture of 1699 – the latter presented four years before his death – Hooke had not only microscopically observed and performed experiments upon countless fossils, often accompanying them with hyper-detailed illustrations that he drew himself, but had also mined ancient myth and history for supportive evidence. Hooke was determined to convince his peers to accept the idea that fossils were of organic origin, mostly extinct, and showed that the earth had changed *significantly* since its creation. That is, that the geologic present can provide evidence of the earth's past.

Hooke lays the foundations for his hypothesis on fossils in the

[28] Hooke, *Discourse of Earthquakes,* 331.

[29] Charles Lyell, *Principles of Geology,* Vol 1, (London, 1830), 399.

*Micrographia*, specifically in the sixteenth observation: *Of* Charcoal *or burnt vegetables*; and the seventeenth: *Of* Petrify'd wood, *and other* Petrfify'd bodies.[30] The sixteenth 'observation' begins with experiments upon a piece of charcoal, though it mostly concerns Hooke's concept of combustion, which according to him is new. However, it ends with experiments on a piece of '*lignum fossile*', appended as an aside to mask Hooke's attack on Francesco Stelluti's conclusions about the origins and causes of the same petrified substance.

Because Hooke's studies on charcoal are important for understanding some of his notions on how all bodies are structured, and how this structure may undergo change – thus how a body may undergo petrifaction – it is necessary to analyse observation sixteen in the intended order before focusing on the piece of petrified wood. Throughout, Hooke uses similitude to convince his reader that, for example, the *lignum fossile* is a piece of petrified wood. I show that coupling similitude with visual pairs gives him greater control over the analogical relations that he constructs between petrified wood and living trees, thereby strengthening his argument. By "visual pair", I mean a simple tool of visual comparison, whether of a pair of images or descriptive text, made of two concrete elements that create a cohesive visual argument by controlling the imagination, and forming new and complex ontological and epistemological relations. This is how Hooke begins his work on fossils and thus Earth history.

### 2.1 Visual Pairs

Taking a 'small round Charcoal', Hooke snaps it in two with his fingers, creating a new surface for both naked-eye and microscopic examination. To the naked eye, the charcoal has 'a very smooth and sleek surface, almost like the surface of black sealing Wax'.[31] Yet, if examined 'with an ordinary *Microscope*', meaning not a powerful one, the surface manifests an 'abundance of those

30 Hooke, *Micrographia*, 100, 112.
31 Hooke, *Micrographia*, 100.

pores which are also visible to the naked eye in many kinds of *Wood*'.[32]

> Of these [pores] there are a multitude in the substance of the Coal, every where almost perforating and drilling it from end to end; by means of which, be the Coal never so long, you may easily blow through it; and this you may presently find, by wetting one end of it with Spittle, and blowing at the other.[33]

This is not Hooke's first use of the deceptively simple "spittle test", which Hooke uses to test whether a body's pores are continuously open like the pores of capillary tubes.[34] "Pores" are the gaps left between the globular particles of which all bodies are made, and in the case of charcoal, Hooke's test confirms that the pores are 'continued open'.[35] When Hooke swaps his 'ordinary *Microscope*' for a more powerful or 'better *Microscope'*, to his delight he finds even more pores, insensible to the naked eye – akin to Galileo pointing his telescope at the heavens and seeing more stars[36] – which make the charcoal stick seem scarcely solid:

> there will appear an infinite company of exceedingly small, and very regular pores, so thick and so orderly set, and so close to one another, that they leave very little room or space between them to be fill'd with a solid body ...[37]

After quantifying the pores to show that a circular area with a diameter of one inch (2.54 cm) contains approximately 725,000 pores, a number that Hooke reckons would be hard to believe had he not counted the pores himself, he mentions having examined the pores of various woods such as '*Cocus, black and green Ebony, Lignum Vitae*', cataloguing their similarities and differences, 'which so prodigiously curious are the contrivances, pipes, or sluces by which the *Succus nutritius*, or Juyce of a Vegetable is convey'd from

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32 Hooke, *Micrographia*, 100.
33 Hooke, *Micrographia*, 100–101.
34 Hooke, Micrographia, Observ. VI. *Of Small Glass Canes.*
35 Hooke, *Micrographia*, 101.
36 Galileo Galilei, *Sidereus Nuncius,* translated by Albert Van Helden (Chicago, USA: University of Chicago Press, 1989). Also see Eileen Reeves, *Painting the Heavens: art and science in the age of Galileo* (Princeton, USA: Princeton University Press, 1997).
37 Hooke, *Micrographia*, 101.

place to place'.[38] Later on, in the *Discourse*, Hooke will use his catalogue of pores to argue for the internal structural similitude between specific living trees and petrified wood, specific marine creatures and marine fossils, and also as an anti-counterfeit measure against artisan-made fossil curios.[39]

The beauty of beginning with charcoal is that Hooke can study structural changes, as mentioned, but also that charcoal allows him to examine a body without its "juices": a counterfactual condition. This is similar to removing air with an air-pump to find out what happens when there is no air, hence what air does.[40] It is important because if Hooke wants to know how juices of petrifaction change a body, he needs to first know what a body is like without its juices, and how this physically affects the conveyors of juices – pores.

Hooke claims that the two types of pores in charcoal, sensible and insensible 'continued open', account for several of the phenomena of coals, such as why charcoal looks black, why it has a shining quality on the surface, and why it is brittle and hard. Here, Hooke's explanation for charcoal's brittleness and hardness is the most important for his studies of fossils studies, because it accounts for their stone-like quality:

> for since all the watery or liquid substance that moistn'd and toughn'd those *Interstitia* of the more solid parts, are evaporated and remov'd, that which is left behind becomes of the nature of almost stone ...[41]

Hooke gives two methods for the creation of charcoal: the first involves charring the wood in a crucible with a packing of sand; the second, a glass retort, which separates the juices from the body, collecting their liquids into a receiver:

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[38] Hooke, *Micrographia*, 101.
[39] Hooke, *Discourse of Earthquakes*, 339.
[40] For a comprehensive account of Hooke's air-pump work with Robert Boyle, see Simon Schaffer and Steven Shapin, *Leviathan and the Air-Pump* (Princeton, USA: Princeton University Press, 1985).
[41] Hooke, *Micrographia*, 102.

> And their manner of charring Wood in great quantity comes much to the same thing, namely, an application of great heat to the body, and preserving it from the free access of the devouring air.[42]

Both methods require great heat and a lack of air, and Hooke analogises the crucible and retort to earthquakes and volcanoes. According to him, just as wood can be turned into charcoal under the right conditions, it can undergo petrifaction under similar conditions, for the earth inside is like a crucible.[43]

Hooke aims to support his argument by analogy with a piece of *lignum fossile* cut from a table gifted to George Ent (FRS 1663) by Cassiano dal Pozzo, with whom Ent had entered into a long correspondence concerning petrified wood.[44] Ent's specimen came from Prince Federico Cesi's estates in the hilly Acquasparta in Umbria, where between 1611–1630 the prince conducted field trips, collecting and cataloguing various specimens.[45] Cesi was one of four founders of the Accademia dei Lincei, though he died before completion of the treatise on fossils, thus leaving it to another of the four – his friend Francesco Stelluti.[46] Stelluti concluded that fossils do not originate from anything that had once lived; and Hooke is certainly aware that he is taking the lynx on directly when he deliberately introduces his trials on the *lignum fossile* as an afterthought, burying the controversial beginnings of his argument for what petrified wood is, and how it came to be that way, at the end of an

[42] Hooke, *Micrographia*, 102.

[43] Hooke, *Micrographia*, 106.

[44] During a December 23 meeting of the Society in 1663, George Ent brought in his *lignum fossile* table, and agreed to allow a joiner to shave off bits which Hooke then experimented upon: in Thomas Birch, *The History of the Royal Society of London*, Vol. 1 (London: Printed for A Millar, 1756-1757), 347. John Evelyn names Cassiano dal Pozzo as the gifter in Evelyn's, *Sylva*: in, John Evelyn, *Sylva, or A Discourse of Forest-Trees and the Propagation of Timber* (London: John Martyn, 1662), 95, where Hooke's findings were also first published. Hooke, *Micrographia*, 105; Hooke, *Discourse of Earthquakes*, 339.

[45] Evelyn, *Sylva*, 95. See also A Cook, 'A Roman correspondence: George Ent and Cassiano dal Pozzo, 1637–55', in *Notes Rec. R. Soc. Lond*. 2005 Jan 22; 59 (1): 5–23. Andrew C Scott, 'Federico Cesi and his field studies on the origin of fossils between 1610 and 1630', Endeavour, Volume 25, Issue 3, 1 September 2001, 93-103. Andrew C Scott and David Freedberg, *Fossil Woods and Other Geological Specimens: the Paper Museum of Cassiano dal Pozzo*, Series B: Natural History, Part 3 (Turnhout: Harvey Miller Publishers, 2000 [published online by Cambridge University Press, 2004]). For Cesi's intense interest in lost and new *naturalia*, also see Vera Keller, 'Nero and the Last Stalk of *Silphion*: Collecting Extinct Nature in Early Modern Europe' (Early Science and Medicine 19 [2014], 424–447.

[46] Scott, 'Federico Cesi and his field studies on the origin of fossils between 1610 and 1630'.

observation seemingly about charcoal and combustion.

Hooke subjects the piece of *lignum fossile* to the same trials as any other wood, first finding that it burns in the open air with a different scent – bituminous instead of resinous – and that it can also be charred, revealing its pores and thus its origins.

> But that which I chiefly took notice of, was, that cutting off a small piece of it, about the size of my Thumb, and charring it in a Crucible with Sand … I found it infinitely to abound with the smaller sort of pores, so extreme thick, as so regularly perforating the substance of it long-ways …[47]

Although the *lignum fossile* lacks the 'bigger kind of pores', Hooke emphasises that 'the smaller kind of pores … have onely hitherto been found in Vegetable bodies'.[48] For him, this microscopic observation provides certainty that the *lignum fossile* was once upon a time a vegetable body. Therefore, to identify it, Hooke compares its small pores with the like pores of various other woods that he has charred until he finds a match: 'comparing them with the pores which I have found in Charcoals that I by this means made of several other kinds of Wood, I find it resemble none so much as those of Firr, to which it is not unlike in grain also, and several other properties'.[49] This is the first visual pair that Hooke creates for his hypothesis on fossils, and he will refer back to it later on in his *Discourse* as an 'experimentum crucis' (see 2.2).[50] Although he does not illustrate the similarities between this *lignum fossile* and a fir tree with drawings, Hooke's textual description is visual: the petrified wood has the same microscopic pores as fir, and the 'grain also'. Since microscopic pores were a rare sight to behold, Hooke mentions the grain as well, painting a picture that is easier on the imagination for the sake of strengthening the relationship between the fossil and the fir.

Starting a polemic that spills into the *Micrographia's* seventeenth observation '*Of* Petrify'd wood, *and other* Petrify'd bodies', Hooke concludes

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[47] Hooke, *Micrographia*, 106.
[48] Hooke, *Micrographia*, 106.
[49] Hooke, *Micrographia*, 106.
[50] Hooke, *Discourse of Earthquakes*, 339.

the sixteenth observation by arguing *against* Stelluti, who, according to Hooke, claims in his 1637 *Trattato del legno fossile minerale nuouamente scoperto* that petrified wood 'is a certain kind of clay or Earth, which in tract of time is turn'd into Wood'.[51] In diametrical opposition to this claim, Hooke states:

> I rather suspect the quite contrary, that it was at first certain great Trees of Fir or Pine, which by some Earthquake, or other casualty, came to be buried under the Earth ...[52]

Moreover, after some unspecified 'long time's residence' in the earth, 'according to the several natures of the encompassing adjacent parts', the fallen bit of fir 'either rotted and turn'd into a kind of Clay, or petrify'd and turn'd into a kind of Stone'. This last statement is a reversal of Stelluti's, as translated by Hooke, and is divided into two either/or causal possibilities that Hooke combines into a continuous process of petrifaction. That is, the wood first rots, and then it is petrified.[53] Here, in the conclusion of the sixteenth observation, Hooke lists several more possible scenarios, ending with the earth as a crucible for charring coals, thereby tying his notions to his arguments from experiment. The fir may have petrified because 'its pores fill'd with certain Mineral juices', which 'coagulated' over time;

> or else from some flames or scorching forms that ... usually accompany Earthquakes, might be blasted and turn'd into Coal, or else from certain *Subterraneous* fires ... being encompassed with Earth, and so kept close from the dissolving Air, charr'd and converted to Coal.[54]

However, Hooke is nothing if not thorough, and also takes care to examine the effects of an over-abundance of juices.

### 2.2 'Characteristick'

[51] Hooke, *Micrographia*, 106. The text that Hooke is referring to is Francesco Stelluti, *Trattato del legno fossile minerale nuouamente scoperto* (Roma: Appresso Vitale Mascardi, 1637), which was written after the death of his friend Cesi, who did not live to see the publication of the Accademei dei Lincei treatise on fossils. Available at: archive.org/details/trattatodellegno00stel.

[52] Hooke, *Micrographia*, 106.

[53] Hooke, *Micrographia*, 106, 107, 109.

[54] Hooke, *Micrographia*, 106.

Two years prior to the publication of the *Micrographia*, in a 1663 meeting of the Society, talk turned from subterraneous trees, to the generation of metals and minerals by 'certain subterraneous juices', to petrified wood.[55] The Helmontian physician Francis Glisson proposed that

> the petrifaction of wood was occasioned by the passing of stony juices into the pores of wood throughout, and by the filling them all up, and so coagulating them, without changing any thing of the figure of the wood.[56]

Glisson probably adopted the idea of 'stony juices' from the Flemish iatrochemist Jan Baptista van Helmont, whose work was already the talk of the town in 1655 – around when Robert Boyle moved to Oxford, employing Hooke as his assistant soon afterwards.[57] Boyle, who replicated several of van Helmont's experiment, had first referenced him back in 1648 – the year of the posthumous publication of the latter's *Ortus Medicinae*.[58] In the *Ortus*, van Helmont claims that a 'stonifying seed', a seminal principle, can 'trans-change' animal and vegetable bodies into stone, not only encrusting them but petrifying them entirely. Further, because animal and vegetable seeds cannot transmute stones, van Helmont argues that the 'stonifying seed … is of a greater efficacy'.[59] Finally, although there are stonifying juices, such as some rivers and natural springs that petrify all manner of things submerged by carrying the seed, van Helmont conjectures that 'a stonifying seed consists in a stony odour alone, which is an incorporeal and invisible Ferment'.[60] So it is reasonable to infer that although Glisson proposed petrifying juices, Hooke and others present at the meeting were already aware of juices, in the manner just

[55] Birch, *The History of the Royal Society,* Vol. 1, 247, 246-248.
[56] Birch, *The History of the Royal Society,* Vol. 1, 248; also see Emily Booth (ed.), *A Subtle and Mysterious Machine: The Medical World of Walter Charleston* (1619–1707) (Dordrecht: Springer, 2015), 87–89.
[57] Booth, *A Subtle and Mysterious Machine,* 87–89.
[58] Booth, *A Subtle and Mysterious Machine,* 87–89.
[59] John Baptista Van Helmont, 'a Treatise of the Disease of the Stone', in *Oriatrike or, Physick Refined … [Ortus Medicae],* English'd by J C Sometime (London: Printed for Lodowick Lloyd …, 1662), 831.
[60] Van Helmont, 'a Treatise of the Disease of the Stone', in *Oriatrike or, Physick Refined … [Ortus Medicae],* 831–832.

described, as an option for explaining fossil formation.

Indeed, in Hooke's circle, van Helmont's conjectures on the processes of petrifaction would inspire discussions as to whether 'incorporeal' described seminal principles, a plastic power (such as the sort that generated fossils in stone according to the *lusus naturae* explanation) or bodies beyond sense limits. For instance, Boyle, whose interest in petrified wood peaked around 1665, and who had every reason to argue for a strictly corpuscular explanation – that is, 'petrifying corpuscles' – expressed ambiguity for a time, seemingly wanting all three options as explanatory devices.[61] Boyle initially conjectured that hardening could be caused by 'Seminall Principles', 'an Allmost Plastick Agent', and 'petrifying corpuscles' piercing into bodies via pores.[62] However, closer to Hooke, who never entertained any notion of a plastic power, by the 1660s Boyle had decided on petrifying particles, and that the key to unlocking this process lay not in the bodies undergoing change but in the variety of juices: 'I … have endeavourd to discover the Differences which I suppose might be found in Petrescent Liquors'.[63] Thus, upon examining a piece of petrified wood, Boyle proposes that the finer the penetrating corpuscles the more perfect the fossil:

> And that great piece of wood … tho it be turn'd into Stone much harder then Marble … retains (to a wonder) it's pristine forme of Wood … which seems to argue a strange minuteness in the petrifying corpuscles.[64]

Later, in 1671, Boyle's corpuscular explanation was supported in the *Metallographia: or, An History of Metals*, both a survey of mining and

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[61] Toshihiro Yamada, 'Hooke-Steno relations reconsidered', in Gary D Rosenberg (ed), *The Revolution in Geology from the Renaissance to the Enlightenment* (USA: The Geological Society of America, Memoir 203, 2009, 107-126), 115; Antonio Clericuzio, 'From van Helmont to Boyle: a study of the transmutation of Helmontian chemical and medical theories in seventeenth-century England' (The British Journal for the History of Science, Vol. 26, No. 3, Sept., 1993, 30 –334), 328. Michael Hunter and Edward B Davis in Robert Boyle, *The Works of Robert Boyle*. Electronic Edition (Virginia, USA: InteLex Corporation, 2003), *Volume 13: Unpublished Writings, 1645-c. 1670*, 'Papers on Petrifaction and Minerology', lvii–lviii (for Boyle's unpublished papers on petrifactions peeking in the mid-1660s). (Henceforth: *The Works*.)

[62] Robert Boyle, *The Works,* Vol. 13, 372, 388–389.

[63] Boyle, *The Works,* Vol. 13, 382, 387–389.

[64] Boyle, The Works, Vol. 13, 388–389.

metallurgy as well as 'the most difficult Questions belonging to Mystical Chymistry' according to its author John Webster, divine, ex-Parliamentary army surgeon, and a 'typical English Helmontian of the mid-seventeenth century'. Webster is perhaps most well-known for his controversy with Seth Ward who took offence at, for example, Webster's claim that Robert Fludd was the picture of Francis Bacon's instauration. (I mention this controversy only briefly to provide a glimpse of one difference of opinion on what enacting Bacon's reforms meant because this is the climate with which Hooke, a follower of Bacon's, had to contend.) [65] Although Webster compliments Boyle's explanation, he also asserts that he has no quarrel with van Helmont's description of the 'petrifying seed' consisting of a 'stony odour of steam, which is an incorporeal and invisible Ferment' (see above for van Helmont's version), he interprets 'incorporeal'

> not to mean merely that the steam is altogether spiritual, as the Schoolmen and Metaphyisicians understand, but that it is so subtile, tenuious and fine, that it is not liable to our sight; and in regard of other more gross bodies, may be called and accounted incorporeal.[66]

In other words, the 'steam' is not a plastic power, but particulate. To bolster his backing of van Helmont's conclusion that fossils are petrified throughout, in the final chapter (XXIX), 'Of the Transmutation of Metals', Webster gathers 'more Authorities' for verification, referencing 'Mr. Boyles Essay of firmness', thereby also reinforcing Boyle's corpuscular choice, as well as 'that accurate and ingenious piece of Mr. *Hooks* Micrography'.[67]

Even more interesting, however, is Webster's reason for taking time to

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[65] Allen G Debus, 'Harvey and Fludd: The Irrational Factor in the Rational Science of the Seventeenth Century', *Journal of the History of Biology*, Vol. 3, No. 1 (Spring, 1970), 99. For Webster's opinion of Bacon, as well as the Webster-Ward controversy, see Stanton J Linden, *Darke Hierogliphicks: Alchemy in English Literature from Chaucer to the Restoration* (Kentucky, USA: University Press of Kentucky, 2014), 270–278. For an alternative interpretation, see Bruce Janacek, *Alchemical belief. Occultism in the religious culture of early modern England* (University Park: The Pennsylvania State University Press, 2011).

[66] John Webster, *Metallographia* (London: Printed by A.C. for Walter Kettilby at the Bishopshead in St. Pauls Church-yard, 1671), 362–363.

[67] Webster, *Metallographia*, 363 (Webster's annotation reads 'Micrograph. Observ. 17 p. 107, 108, etc/ Vid. Philo. Trans. n. 6, p. 101').

discuss petrifactions, in particular petrified wood, in a review of modern ideas on metals, for it provides both a novel and peer perspective of Hooke's work, revealing alchemical themes in Hooke's observations of and experiments upon fossils. To begin, Webster claims that he is examining transmutations *not* of metal 'to shew some sorts … that are common and obvious', that is, to reveal how common a natural process it is. He thus divides types of transmutations into two categories: of art, such as turning one metal into another, and those 'produced by Nature' such as the 'petrifying of wood'. His motivation is to show that transmutation 'is no such impossible or wonderous thing, as many that would seem wise and learned do labour to make manifest'.[68]

Webster's initial explanation of how things are transmuted makes no distinction between art and nature, for according to him the processes occur in 'three ways, or by two of them, or all joined together': either by adding something to, or subtracting something from, the body undergoing change, or 'by reason of motion so to alter, dispose, and order the contexture of the parts, that thereby it appeareth another thing than what it was before.'[69] Although Webster neglects to mention Hooke again in this chapter, as we will soon see, he clearly has Hooke's seventeenth and maybe sixteenth *Micrographia* observations in mind when instancing petrified wood to argue that the process of petrifaction in general is

> not only an Aggregation of these small stony particles, and an Incrustation upon the out-side … but even that the substance … and the small atomes of them are merely petrified as far as our eyes, *or the best Microscopes* can inform us.[70]

Webster adds that although thicker pieces of wood take longer to petrify 'both in the Internal and External parts', the point is that they are '*really changed* into a stony substance'.[71] Hooke had, some time before 1668, attempted to

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[68] Webster, *Metallographia*, 356, 359.
[69] Webster, *Metallographia*, 358.
[70] Webster, *Metallographia*, 359–360. Italics added.
[71] Webster, *Metallographia*, 361. Italics added.

petrify wood artificially. In his first *Discourse of Earthquakes* lecture, he mentions in passing that (unlike nature) he has 'never yet been able to petrify a Stick throughout'.[72]

Webster argues that nature's transmutation of petrified wood and animals is 'more wonderful' than the transmutation of metals by art because the former changes not only the substance but also its '*genus*': animal or vegetable to stone versus metal to metal.[73] While he repeats the alchemical adage that art not only imitates but also improves nature by speeding up metal maturation, in Webster's opinion this is not actual transmutation: although both 'vulgar Chymists' and 'mystical chymists' commonly apply the verb 'transmute' to metals, 'truly the thing they do, is only to maturate and meliorate' baser metals ultimately into gold.[74] Thus despite petrifaction being far more common, Webster nevertheless exalts the natural kind (animals and plants to stone – a change of genus):

> there is no cause to account the one strange or impossible, and the other not, except that it be by reason that petrifying is more common, and the change of Metals, but seldom or rarely seen.[75]

Indeed, concerning fossils, the transmutation of one metal into another was not considered to be such a grand achievement in comparison to other forms of metamorphosis, such as a caterpillar changing from a chrysalis into a butterfly, or Lot's wife petrifying into a pillar of salt, or the stalagmite witch at Wookey Hole Cave, petrified like a fossil by a 'learned' clergyman from

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[72] Hooke, *Discourse of Earthquakes*, 293.

[73] Webster, *Metallographia*, 370, 365.

[74] Webster, *Metallographia*, 364. For examples of Webster's use of the terms 'vulgar' versus 'mystical' chymists and chymistry, see 190, 72. The idea of metals growing, maturing and meliorating in the earth is an Aristotelian one, and gold was traditionally prized for being the rarest, most inert metal. As explained by Stanton Linden, in Stanton J Linden, *The Alchemy Reader: From Hermes Trismegistus to Isaac Newton* (Cambridge: Cambridge University Press, 2003), 13, 'Well into the seventeenth century, explanations of the natural origin of metals were largely Aristotelian, as set forth in his *Meteorology*. They were based on the theory of the four elements (derived from Empedocles and Plato), the idea of a single, underlying prime matter; and vapors and exhalations – the moist and the dry – as the "parent principles" of all things that were quarried and mined'. Aristotle and E.W. Webster (trans.), *Meteorologica* (Internet Classics Archive. Retrieved from http://classics.mit.edu/Aristotle/meteorology.mb.txAristotle, 1923). Accessed 2020, during a lockdown.

[75] Webster, *Metallographia*, 366 (reiterated on page 370).

'Glaston'; or even the metaphysical poet John Donne's metaphorical line in *Resurrection, imperfect* that Christ 'For these three daies become a minerall'.[76] As these examples show, notions about various sorts of transmutations saturated English culture and religion. It may be that Thomas Browne, a physician, and follower of Bacon's, engaged in a similar line of thought when penning a comparison of the philosopher's stone to the silkworm:

> The smattering I have of the philosophers' stone (which is something more than the perfect exaltation of gold) hath taught me a great deal of divinity … Those strange and mystical transmigrations that I have observed in silkworms .... There is in these works of nature, which seem to puzzle reason, something divine; and hath more in it than the eye of a common spectator doth discover.[77]

In any case, it is interesting to note that Webster's view of petrifaction parallels the paradox of inaccessible ubiquity found in the famous *Emerald Tablet* – attributed to Hermes Trismegistus, legendary founder of alchemy, peer of Moses – and the numerous interpretations of it in alchemical literature.[78] Namely, that the ubiquitous prime matter, 'founde in eury place, in euery time, in euery man', as put in the *Secretum secretorum*, was the sole ingredient of the rare Philosopher's Stone.[79] In parallel, for Webster, the so-called

[76] John Read, *From Alchemy to Chemistry* (New York: Dover Publications, Inc., 1957), 4, 14. Thomas Percy, *Reliques of Ancient English Poetry* … (London: J Templeman, 1839 [6th ed]), 85: 'He crost the water, blest the brooke …/ The ghastly hag he sprinkled o'er,/ When lo! where stood a hag before,/ Now stood a ghastly stone.' Read, *From Alchemy to Chemistry*, 4. Also see H E Balch, *The Mendip Caves* (Place Unknown: Butterworth-Heinemann, 1947), 9. John Donne, Poems, by J D With elegies on the authors death (London, 1633), Early English Books Online Text Creation Partnership 2011, https://quod.lib.umich.edu/e/eebo/A69225.0001.001/1:50?rgn=div1;view=fulltext, accessed 2 March 2021.

[77] Thomas Browne, and Simon Wilkin (ed), *Religio Medici*, in *The Works of* …, Vol. 2 (London: G Bell, 1888) Sect. XXXIX, 383.

[78] Jennifer M Rampling, *The Experimental Fire: Inventing English Alchemy, 1300–1700* (Chicago and London: University of Chicago Press, 2020), 12; Theodore Ziolkowski, *The Alchemist in Literature: From Dante to the Present* (Oxford: Oxford University Press, 2015), 7. See also Lyndy Abraham, *A Dictionary of Alchemy* (Cambridge: Cambridge University Press, 1998), 70; Linden, *The Alchemy Reader*, 27; and Read, *From Alchemy to Chemistry*, 22–24. According to Charles Nicholl, the first English translation of the *Emerald Table*, titled the *Smaragdine Table of Hermes Trismegistus,* was in Roger Bachon, *The Mirror of Alchimy* (London: Printed for Richard Oliue, 1597), 23, 48: in, Charles Nicholl, *The Chemical Theatre* (London: Routledge & Kegan Paul, 1980).

[79] Rampling, *The Experimental Fire*, 12, fn 30: 'Translation based on Ashmole 396 (fifteenth

transmutation of metals is 'rarely seen', yet the 'more common' transmutation of 'petrifying' is found everywhere in the earth. This kind of rhetorical construction is not surprising when the Hermetic *prisca theologia* and *sapientia* of alchemy is examined in a slightly broader context, for it is deliberately akin to theological language where paradox expresses 'transcendent values' so that 'the despised and rejected is *therefore* precious' (*via negativa* or by negative apophatic theology).[80] It is a theme of utmost importance to Hooke, who treats it literally.

Thus, similarly to Webster's argument that the frequent is 'more wonderful' and the scarce is mere maturation, celebrating the common and abundant over the rare was a principle that Hooke promoted throughout his work. Nothing, says Hooke in the *Micrographia*, 'is comparable to the deckings of a Peacock; nay, to the curiosity of any feather … nor to that of the smallest and most despicable Fly.'[81] With respect to the animal kingdom, becoming wiser by wonder of the common was an ancient inversion, reshaped to include new instruments and investigative practices by diverse mid-seventeenth-century natural historians, physico-theologians and experimentalists.[82] Three years later, in the beginning of his first *Discourse* lecture, Hooke is to be found explicitly defending the worth of fossils from detractors who call them 'common':

> The most part of Mankind … neglect the common and most obvious; whereas in truth, for the most part, they are the most considerable. And the greatest part of the Productions of Nature are to be seen every where, and

century), in *Secretum Secretorum: Nine English Versions*, ed. Mahmoud Manzaloui (Oxford: Oxford University Press, 1977), 67'. See also the seminal study by Mircea Eliade, *The Forge and the Crucible: the Origins and Structure of Alchemy* (Chicago and London: University of Chicago Press, 1978), 163, 165: Eliade claims that the prime matter's ubiquity corresponds with the rare Philosopher's Stone.

80 Gareth Roberts, *The Mirror of Alchemy: Alchemical Ideas and Images in Manuscripts and Books from Antiquity to the Seventeenth Century* (Toronto: University of Toronto Press, 1994), 70–71, 70.

81 Hooke, *Micrographia*, 152. I'd like to thank one of my anonymous reviewers for indicating that this is a Baconian principle also followed by Robert Boyle.

82 Edwards, *Milton and the Natural World*, 41; 'Go to the ant, thou sluggard; consider her ways, and be wise' (*Proverbs*, 6:6, KJV).

> by every one, though, for the most part, not heeded or regarded, because they are so common.[83]

Hooke depicts fossils as serious objects of intellectual coinage: for him, as for Webster and others, the very acts of these common transmutations were extraordinary – fossils were a ubiquity as valuable as gold, and the thing to be ameliorated was not metal but knowledge of nature. In 1686/'87, Hooke asks his audience 'how will this Knowledge [of fossils] be an improvement of Natural Knowledge?'[84]

This is how 'this Knowledge' starts, and the rest we will explore henceforth: Following Glisson's remark on petrifying juices back at the 1663 meeting, Hooke produced a piece of petrified wood, previously submitted by the physician Jonathan Goddard, which according to Hooke's microscopic observations 'still appeared porous'.[85] Cutting the piece 'sideways', Hooke subjected the petrified wood to exhaustive qualitative and quantitative tests (compared to regular wood), delivering a report that would become the bulk of the *Micrographia's* seventeenth observation, 'Of Petrify'd wood, and other Petrify'd bodies'. Here, he would also wed the Helmontian thoughts voiced by Glisson on petrifying juices and pores to his own ideas on fossil origins, formation and identification.[86] Most importantly, with the experiments showcased in both the sixteenth and seventeenth observations, Hooke invented a microscopic comparative-anatomical approach, a new visual language with which to read the characteristic marks of fossils in the book of nature. Using this approach, Hooke was confident that he could identify the species of tree to which Goddard's petrified wood had once belonged, or what sort of creature a petrified shell had once been, even if some metamorphosed parts were missing. These characteristic marks were the profits gained by probing beneath what the naked eye could see; they could be used to 'spell, and read the

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83 Hooke*, Discourse of Earthquakes*, 280.
84 Hooke, *Micrographia*, 'The Preface', unpaginated.
85 Birch, *The History of the Royal Society*, Vol. 1, 248.
86 Birch, *The History of the Royal Society,* Vol. 1, 248; 260–262 (a subsequent meeting); Hooke, *Micrographia*, 107.

Book of Nature'; not just an idea, but a practical tool.[87]

Having determined what happens physically to the pores of wood when all juices are removed via charring, Hooke now turns to investigating what happens when a body is exposed to an overabundance of 'moystures' by examining rotten wood, because all fossilised wood that he has seen seems 'to have been rotten Wood before the petrifaction was begun'.[88] In the *Micrographia's* seventeenth observation, he describes finding 'a huge great Oak, that seem'd with meer age to be rotten as it stood', and confirms that 'the grain, colour, and shape of the Wood was exactly like' petrified wood. When he views a piece of this rotten oak under a microscope, to compare its pores with those of charcoal, Hooke notes a telling difference.

> I found, that all those Microscopical pores, which in sappy or firm and sound Wood are fill'd with the natural or innate juices of those Vegetables, in this they were all empty, like those of Vegetables charr'd; but with this difference [the difference between the charred and the rotten], that they seem'd much larger then I have seen any in Char-coals …[89]

During the process of investigating rotten versus charred wood, to understand how petrified wood first rots and is then charred, Hooke postulates that the pores of charcoal are smaller, and that the pores of rotten wood are larger, relative to 'sound Wood', because when wood is charred quickly under great heat, its parts contract, thereby shrinking the pores; whereas, when wood rots,

> the natural juice seems onely to be wash'd away by adventitious or unnatural moisture; and so though the natural juice be wasted from between the firm parts, yet those parts are kept asunder by the adventitious moystures, and so by degrees settled in those postures.[90]

Moreover, after obtaining a new piece of petrified wood to experiment upon,[91] Hooke is also in a position to note that 'the pores [in the petrified wood]

[87] Hooke, *Discourse of Earthquakes*, 331, 338.
[88] Hooke, *Micrographia*, 107.
[89] Hooke, *Micrographia*, 107.
[90] Hooke, *Micrographia*, 107.
[91] The petrified wood experimented upon in observation seventeen is the piece that Dr Jonathan Goddard brought with him to a meeting of the Royal Society in June 1663 (Birch, *The History of*

were somewhat bigger than those of Charcoal' too, meaning that they were closer in size to the pores of rotten wood, which makes sense according to Hooke's hypothesis that fossilised wood was once alive, and that it rots before petrifaction. Hooke also hastens to add that 'though they were a little bigger, yet did they keep the exact figure and order of the pores of Coals and of rotten Wood, which last also were much of the same cize'.[92] These two observations serve a decisive function in Hooke's developing catalogue of "characteristic pores", which, as mentioned, he will proclaim a *crucial experiment* three years later in a *Discourse* lecture. That is, no matter the extreme physical changes of charring, moisture, rot and petrifaction, a body's pores still retain their characteristic places, allowing for identification via similitude.

> [It resembled wood] in that all the … *Microscopical* pores of it appear (both when the substance is cut and polish'd *transversely* and *parallel* to the pores of it) perfectly like the *Microscopical* pores of several kinds of Wood, especially like and equal to those of several sorts of rotten Wood … [93]

In all of Hooke's descriptions it is clear that the internal, microscopic *structure* of a body takes precedence over external, naked-eye appearances that may deceive. Hooke's challenge is to convince his audience that microscopic, material pores are important objects of investigation in the new science; further, that this new kind of insensible similitude, obvious only with new instruments, is the way that petrified substances should be identified.

Yet when Hooke attempts to delineate the difference between charcoal pore size versus petrified wood pore size in *Scheme X* (Figure 2), with a pair of

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*the Royal Society of London*, Vol. 1, 2, 244), *before* Hooke obtained a piece of Ent's table in observation sixteen. Indeed, Hooke read a good part of observation seventeen before the Society shortly thereafter (compare Hooke, *Micrographia*, 108, with Birch, *The History of the Royal Society of London*, Vol. 1, 260). In a 1664 Society meeting, Hooke presented another paper on petrifactions, which was also part of the *Micrographia*: 'There was a paper of Mr. HOOKE'S concerning petrifactions, designed by him as part of his microscopical book, then in the press. The Society approved of the modesty used in his assertions, but advised him to omit what he had delivered concerning the ends of such petrifactions' (Birch, *The History of the Royal Society of London,* Vol. 1, 463). See also Robert Hooke, Hooke Folio: CELL/RS/HF_010 © *Centre for Editing Lives and Letters* (London: Royal Society, 2007) http://www.livesandletters.ac.uk/projects/hooke-folio-online.

92 Hooke, *Micrographia*, 107.

93 Hooke, *Micrographia*, 108.

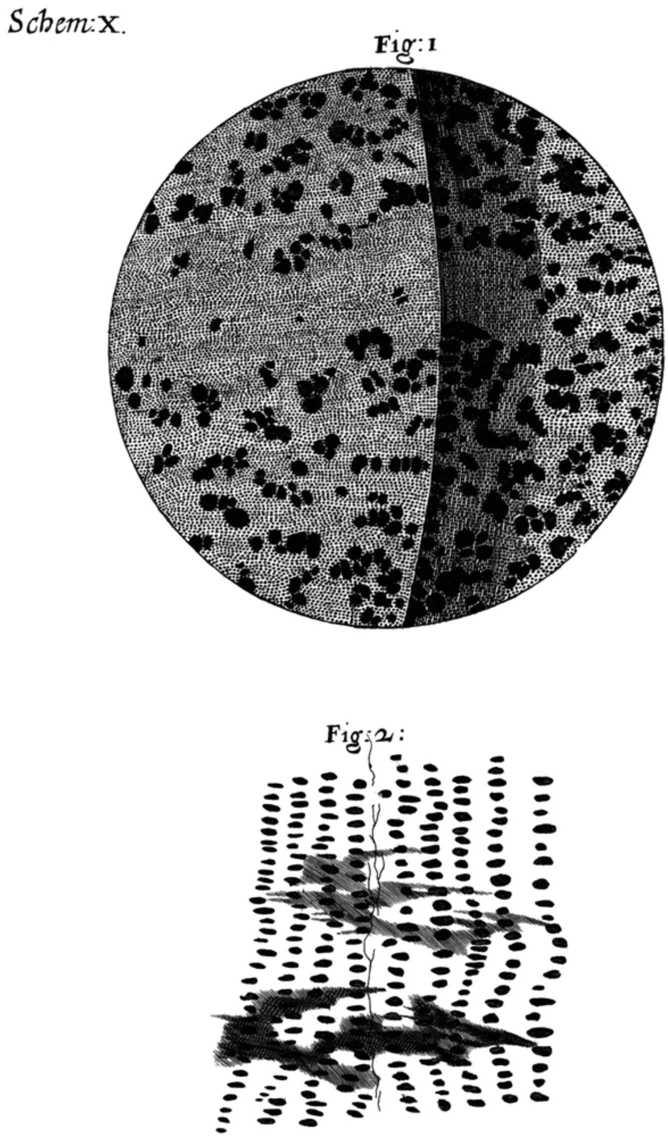


*Figure 2: Scheme 10 in Hooke's* Micrographia, *showing his hand-drawn micrographs of pores in charcoal (fig. 1) and petrified wood (fig. 2).*

hand-drawn micrographs on the same plate, which represent the 'small continued open' pores in charcoal ('Fig: 1' in my Figure 2) and the same kinds of pores in petrified wood ('Fig: 2' in Figure 2) respectively, he fails to form a visual pair or a cohesive visual argument. Although each drawing serves its purpose when viewed alone, according to Hooke, the side-by-side comparison of pores fails to capture the size difference, because he used a better microscope when drawing the petrified wood ('Fig: 2'), which 'magnify'd the object above six times more in Diameter then the Microscope by which those pores of Coal were observ'd' ('Fig: 1').[94] (Hooke neglects to mention why he needed to use two different microscopes in the first place.) At best, the pair represents an artefact caused by using two different magnifications, abstracting the relation, and robbing Hooke's pores of their epistemological power. Hooke shows that he is aware of the problem by pointing it out.

He will point it out indirectly again in a *Discourse* lecture penned in 1668, when he warns specifically against studying the 'Chracteristicks' of 'Fossile-

[94] Hooke, *Micrographia*, 107.

Shells and Petrifactions' from 'reading their Descriptions and seeing their Pictures', for 'without inspection of the things themselves, a Man is but a very little wiser or more instructed by the History, Picture, and Relations concerning Natural Bodys'.[95] This may seem like a commonplace early modern anti-Aristotelian rant against learning from books; or a regurgitation of the Royal Society's motto 'nullius in verba'; or an argument against commiting the fallacy of authority.[96] But when coupled with Hooke's failed attempt at constructing a visual pair from charcoal versus petrified wood pores in the *Micrographia*, it is *also* Hooke's introduction to instructing his audience in practicing *his* new visual means of fossil identification using 'Characteristicks' instead of relying only on secondhand renditions of surface appearances. Hooke is trying to enforce nothing less than a new, practical law of vision for the viewing of petrified bodies. Hooke's retort against reliance only on a scant handful of descriptions and illustrations in books ('a Picture or two of the Shells, and some Stones') expands into his analogising 'characteristicks' with the 'Characters' of nature's grammar, followed by concrete examples of examinations of various bodies, both fossilised and living, demonstrating his probabilistic argument that 'the more of these certain Characteristicks of the several Species of Bodies there are known, the greater certainties and assurances will be afforded by the artificial and strict examination of them'.[97]

For example, Hooke criticises the 'imperfect and inaccurate Description of this so curious a Fish … the *Nautilus*'. Listing '*Aristotle, Pliny, Bellonius, Piso, Cardan, Fauconerius*, and others', he berates them in unison,

> for by all those descriptions I cannot imagine any one can get any tolerable Idea or Notion, what the make of so wonderful a Fish must be that has such

[95] Hooke, *Discourse of Earthquakes*, 338.

[96] For a study of Royal Society fellows protesting too much (in the Shakespearean sense) with respect to their own bookishness versus their anti-bookish rants, see the excellent book, Richard Yeo, *Notebooks, English Virtuosi, and Early Modern Science* (Chicago, USA: University of Chicago Press, 2014).

[97] Hooke, *Discourse of Earthquakes*, 338–339.

> an admirable quality as to buoy himself as *Pliny says* … from the bottom of the sea … [and] presently to sink himself down again to the bottom.[98]

Hooke explains that since both the shell and this property of buoyancy and sinking at will are peculiar to the nautilus, 'the artificial and strict examination' of a shell should divulge 'the Engine which performeth this admirable Exploit'.[99] He notes that 'the whole Shell is divided into a multitude of Cells' – the equivalent of pores in wood – 'separated and distinguished one from another by several Diaphragmes'. And he postulates that the nautilus can fill the 'Cells' of its shell with water to sink, and an 'artificial Air', produced by its gut, 'to buoy [itself] up'.[100] Note that these are all strictly internal characteristics unique to the nautilus, thus characteristic to that 'Species'. External 'accidental Properties', which are a cause of 'great variety' amongst nautili shells, are *not* characteristic features of its form:

> flating, crenating, depressing, ridging, stringing, and the like, ornamenting, as it were, of the outward sides of this volute conical Body, and the undulation and foliation, as I may call it, of the Diaphragme … are not to be looked upon as Characteristicks or Differences to denominate a new Species.[101]

Finally, it is important for Hooke to win over his audience because the 'varieties of Natural Bodies' are so vast, the collection so incomplete, 'that 'tis almost impossible for any one Examiner or Describer to take notice of them, or so much as to have any imagination of them'.[102] That Hooke has his *Micrographia* observations in mind during the writing of this 1668 lecture becomes obvious in the subsequent paragraph when he references his trials on Ent's *lignum fossile* from the sixteenth observation, in preparation for reiterating his claims and supportive arguments on the importance of characteristic pores.

In a defensive manoeuvre against several objections raised against his

98 Hooke, *Discourse of Earthquakes*, 340.
99 Hooke, *Discourse of Earthquakes*, 340.
100 Hooke, *Discourse of Earthquakes*, 340.
101 Hooke, *Discourse of Earthquakes*, 339.
102 Hooke, *Discourse of Earthquakes*, 338.

fossils hypothesis, Hooke sharpens the nib of his quill against Stelluti again when he proclaims:

> By the examination, I say, and discovery of the microscopical Pores thereof with a Magnifying-Glass to be like those of Firr, I produced a better Argument that it was really Firr than any *Franciseo Stelluti* has argued to prove it Earth.[103]

Hooke's 'better Argument' remains unchanged: knowing the characteristic internal structure of a body, namely, the pores, is better than relying on 'the outward Figure and Appearance thereof, which may be artificially or accidentally imitated'. And although Hooke continues to tirelessly espouse a variety of experimental techniques, 'for the more of Testimonies and Confessions are fetch'd from these Examinations and Wracking, the greater will be the Evidence of the true Nature of those Substances so examin'd', according to him, where the study of fossils is concerned, the microscopic examination of a body's characteristic pores is an *experimentum crucis* – a crucial experiment 'to save all further Enquiries'.[104]

> These are such marks as I call Characteristicks, which expressly determine and limit the Nature and Species of the Body under Consideration.[105]

But just as in the *Micrographia* when Hooke failed, because of a difference in magnification, to construct a visual argument by pairing drawings of charcoal pores with pores of petrified wood, here pores and cells lose their epistemological power because they are 'characteristick' (as opposed to accidental), novel, unique objects. This is a problem characteristic of the new science, and it impedes Hooke's attempt at neutralising the visual side of fossils – for example, the excitement and wonder of a stone resembling a fish – to make his audience see and observe the characteristic properties within. Therefore, Hooke's idea of characteristics needs some excavating, because with it, Hooke attempts to take the study of fossils and Earth history into a new

[103] Hooke, *Discourse of Earthquakes*, 339.
[104] Hooke, *Discourse of Earthquakes*, 339.
[105] Hooke, *Discourse of Earthquakes,* 339.

direction.

### 2.3: Bacon's Instauration

Explicit in Hooke's approach to the study of fossils was an idea of Francis Bacon's, but not the usual watchwords on induction and reasoning. These words, as Paula Findlen argues, have been underscored by scholars 'at the expense of other intellectual issues', such as Bacon's modification of alchemy and natural magic (though my focus is on the former), relabelled as 'natural history', upon which natural philosophy depended.[106] It needs to be reiterated that I do not mean the laboratory aspect and traditional practices of alchemy, which other historians of science have devoted considerable attention to, nor of the experimental context that these practices created.[107] Rather, I mean Bacon's proposed alchemy reformation of the Paracelsian world-picture of signatures and sympathies, which for him (and Hooke) was as much a religious and social reformation as it was a natural-historical and natural-philosophical one, and Hooke's use of it in his fossil studies (as well as some other observations that he made as the curator of experiments for the Royal Society of London). Bacon's idea was a proposed reparation of the Paracelsian world-picture of signatures and sympathies, which Bacon thought had been overly marred by the imagination. Hooke's approach to fossils was a practical, theoretical and metaphysical implementation of Bacon's keystone for an alchemical reformation: the idea that 'characteristick marks', what Bacon calls 'true names', were forms stamped not *on* things but physically *in* things themselves.[108] Hooke's way of identifying the origin of fossils was an attempt to

[106] Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', 239–260, 248. Also see Stephen Gaukroger, Francis Bacon *and the transformation of early-modern philosophy* (Cambridge: Cambridge University Press, 2004 [2001]), 195–196.

[107] For a history of alchemy that focuses on its experimental laboratory aspects, see Lawrence M Principe, *The Secrets of Alchemy* (Chicago and London: The University of Chicago Press, 2013). For a balanced review of Principe's work, see Anna Marie Roos, 'The experimental approach towards a historiography of alchemy (reviewing L M Principe. *The Secrets of Alchemy*)', *Studies in History and Philosophy of Biological and Biomedical Sciences* 44 (2013), 787–789.

[108] For 'true names', see, for example, Francis Bacon, *Valerius Terminus of the Interpretation of Nature* (1603), in *The Works of Francis Bacon*, edited by James Spedding, Robert Leslie Ellis

practise these ideas and ideals, because studying petrifaction in this manner helped him to understand how a once-living thing could be turned into stone and metal, to uncover nature's language, and therefore to attempt to restore mankind to a state of Edenic perfection. Hooke was a virtuoso, freely borrowing and mixing specialist knowledge from fields not perceived as disparate to him and his peers – fields that historians often categorise as distinct.[109] With these skills, and in this environment where ancient and modern met, mixed and reacted, Hooke's approach to fossils was a practical, theoretical and metaphysical implementation of Bacon's keystone for an alchemical reformation: the idea that 'characteristick marks', what Bacon calls 'true names', were forms stamped not *on* things but physically *in* things themselves.[110]

### 2.3.1 Alchemy Reformation

Hooke's sincerity, his practical and theoretical processes of reading the book of nature to piece together an Earth history from fossils, and his investigation and interpretation of characteristic marks, were rooted in Francis Bacon's reformative ideas on knowledge in general, and alchemy in particular. Although Bacon rejected many of Paracelsus's ideas, he shared with him the ambition of moving alchemy in a new direction: where Paracelsus initiated iatrochemistry, Bacon aimed to redirect alchemy's focus to natural history, natural philosophy, and public knowledge.[111] All of the ideas discussed in this section were adopted by Hooke in his studies of fossils and petrifaction.

According to Bacon, 'All the philosophy of nature which is now received,

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and Douglas Denon Heath (Reprinted, Stuttgart: Friedrich Frommann, 1963 [1859]), III.222. [Henceforth: *Works.*]

109 See Bruce Janacek's similar argument with respect to Elias Ashmole cross-pollenating his work as an antiquary with his alchemical studies, in Bruce Janacek, 'A Virtuoso's History: Antiquarianism and the Transmission of Knowledge in the Alchemical Studies of Elias Ashmole', *Journal of the History of Ideas*, Volume 69, Number 3, July 2008, 395–417, 397.

110 For 'true names', see, for example, Bacon, *Valerius Terminus of the Interpretation of Nature* (1603), in *Works*, III.222.

111 Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century'.

is either the philosophy of the Grecians, or that other of the alchemists'. The alchemical philosophy has 'foundation in imposture, in auricular traditions and obscurity' and is 'gathered … out of a few experiments of a furnace'.[112] Despite his rejection of alchemists' claims to elect esoteric knowledge – which grates against his goal to make this knowledge public and a profession – Bacon echoes many an alchemical text when agreeing that alchemy's '*ends are noble'; it has* provided natural philosophy with 'a great number of good and fruitful inventions and experiments, as well for the disclosing of nature as for the use of man's life'.[113] However, most of the means to those ends are flawed because alchemy has 'better intelligence and confederacy with the imagination of man than with his reason'.[114] Bacon's perceived problem – over-indulging the mind's image-making faculty – is interrelated with two other issues: a confusion of categories between religion and natural philosophy; and alchemy's richly figurative mode of discourse (poetry instead of literal or plain speech).[115]

Bacon divides man's 'learning' traditionally and broadly into three parts: '*history* to his *memory*, *poesy* to his *imagination*, and *philosophy* to his *reason*'.[116] Further, 'Poesy is a part of learning … extremely licensed, and doth truly refer to the imagination'. The imagination, 'being not tied to the laws of matter, may at pleasure join that which nature hath severed, and sever that which nature hath joined; and so make unlawful matches and divorces of things'. Because the art of poetry is not tied to 'laws of matter' like the body, it

[112] Bacon, *Mr Bacon in Praise of Knowledge*, in *Works*, Vol. 1, 79. https://en.wikisource.org/wiki/Page%3AThe_Works_of_Francis_Bacon_(1884)_Volume_1.djvu/207. Accessed June, 2021.

[113] Francis Bacon, and G W Kitchin (ed), *Of the Advancement of Learning* (London: J M Dent & Sons Ltd, 1930 [London, 1605]), 30. (Henceforth: *Advancement of Learning*.)

[114] Bacon, *Advancement of Learning*, 29. Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', in Donald R Kelley (ed), *History and the Disciplines: the Reclassification of Knowledge in Early Modern Europe* (Rochester, 1997), 239, 247. See also Stanton J Linden, *Darke Hierogliphicks: Alchemy in English Literature from Chaucer to the Restoration* (Kentucky: The University Press of Kentucky, 2008 [1996]), Chapter IV: The Reformation of Vulcan, especially 107–110.

[115] According to Stephen Gaukroger, in overturning the primacy of poetry, and therefore Sidney's claims, Bacon makes the natural philosopher more important than the poet: Gaukroger, *Francis Bacon and the transformation of early-modern philosophy*, 58.

[116] Bacon, *Advancement of Learning*, 69.

can make 'unlawful matches and divorces', thus it cannot be trusted, and is of little use to philosophy.[117] Indeed, according to Bacon's critical approach to all kinds of knowledge in the *Advancement of Learning* (1605), over-reliance on 'imagination and belief' rather than 'a laborious and sober inquiry of truth', had corrupted the science of alchemy, which 'pretendeth to make separation of all the unlike parts of bodies which in mixtures of natures are incorporate'.[118] Because alchemists could not separate their fantasies from the things they attempted to perfect, alchemy could only pretend to make separations. Bacon's problematisation of poetry relates not only to the poetic mode of alchemical discourse but also to the Paracelsian doctrine of signatures – where exterior signatures grant knowledge of the interior essence of a thing – the microcosm-macrocosm world view essential to traditional alchemical metaphysics. Therefore, not only is alchemical discourse poetry but so is the doctrine of signatures: both can 'join that which nature hath severed, and sever that which nature hath joined; and so make unlawful matches and divorces of things'.

Bacon argues that the traces left by God were *not* signatures stamped *on* things, so they require no leap of the imagination to recognise resemblances – no extra layer of interpretation is necessary.[119] For example, in the *Advancement of Learning*, the imagination is responsible for 'the ancient opinion that man was *microscosmus* – an abstract or model of the world – [that] hath been fantastically strained by Paracelsus and the alchemists', for whom alchemy could achieve its ends because of the correspondences between things. That is, man as a microcosm of the macrocosm experienced correspondences via sympathy, experiences triggered not by reason but by the imagination; and transmutation, whether metallurgical, medicinal, or

[117] Bacon, *Advancement of Learning*, 82. See also Cindy Hodoba Eric, 'Artificial Apertures: The Archaeology of Ramazzini's *De fontium* in Seventeenth-Century Earth Historiography' (*Centaurus*, Vol. 62, Issue 3, August 2020, 522–541), 526.

[118] Bacon, *Advancement of Learning*, 29, 101. Linden, *Darke Hieroglyphicks,* 2–3, 63, 107. The primacy of reason and truth over the imagination is a commonplace commonly attributed to Bacon: see, for example, D R Kelley and D H Harris Sacks (eds), *The Historical Imagination in Early Modern Britain*, 4, 10.

[119] Also see Bono, *The Word of God and the Languages of Man,* 233.

other, provided alleged proof of matter's unity.[120] Bacon reiterates and expounds upon this opinion in the preface to *The Phenomena of the Universe*, the third part of *The Great Instauration* (1620), where he again rejects the doctrine of signatures and the macrocosm-microcosm world view because both rest on faulty foundations of the imagination:

> we clearly impress the stamp of our own image on the creatures and works of God, instead of carefully examining and recognizing in them the stamp of the Creator himself. Wherefore our dominion over creatures is a second time forfeited.[121]

Moreover, just as 'miracles have been wrought to convert idolaters and the superstitious', according to Bacon, heathens 'supposed the world to be the image of God, and man to be an extract or compendious image of the world'. But just as wares exhibit the artisan's skill 'not his image', the world displays the work of God's hands. The scriptures 'never vouchsafe to attribute to the world that honour, as to be the image of God, but only *the work of His hands*; neither do they speak of any other image of God but man'.[122] In the *New Organon*, this criticism includes not only God's works but God's word:

> Some of the moderns have with extreme levity indulged so far as to attempt to found a system of natural philosophy on the first chapter of Genesis… and other parts of the sacred writings.[123]

Here, Bacon has not only Puritans but also, again, Paracelsus and his disciples in mind. Paracelsus, and others after him, interpreted *Genesis* as an alchemical account of creation; but for Bacon, conflating the human and divine creates

[120] Bacon, *Advancement of Learning*, 90. For Paracelsus's and Paracelsian ideas on the macrocosm and the microcosm, see the great work Owen Hannaway, *The Chemists and the Word: the Didactic Origins of Chemistry* (Baltimore: John Hopkins University Press, 1975); see also Bono, *The Word of God and the Languages of Man,* 134–136. For the unity of matter, see, for example, Abraham, *A Dictionary of Alchemy*; Read, *From Alchemy to Chemistry*; Nicholl, *The Chemicall Theatre*.

[121] Bacon, *The Phenomena of the Universe*, in *Works*, Vol. V, p. 132. See also Bono, *The Word of God and the Languages of Man,* 231; for Paracelsus's explanation of the doctrine of signatures in practice, see Bono, *The Word of God and the Languages of Man*, 134–135.

[122] Bacon, *Advancement of Learning*, 88.

[123] Bacon, *Novum Organum*, in *Works*, Vol. 4, 66.

'not only a fantastic philosophy but also an heretical religion'.[124]

### 2.3.2 Bacon's Reformed Alchemy

But despite Bacon's admonishment of Paracelsus and his followers, his own cosmology was 'semi-Paracelsian'; moreover, he was not above mixing natural philosophy and religion when it came to providing historical foundations and justification for his proposed reform, arguing that man lost power over nature after Adam's fall, retaining only a pale shadow of it thanks to the arts.[125] Thus, Bacon claims, the end of knowledge is

> a restitution and reinvesting, in great part, of man to the sovereignty and power, for whensoever he shall be able to call the creatures by their true names, he shall again command them, which he had in his first state of creation.[126]

I suggest that this was also one more way for Bacon to burn away what he perceived as the dross on alchemy: by claiming that his reformed alchemical approach could restore to man the Adamic language ('true names'), Bacon was also attempting to appropriate and expurgate alchemy's antiquity, transforming Adam the first alchemical adept into Adam the first natural historian (meaning Bacon's redefinition – see the subsequent subsection) and philosopher.[127]

Alchemy further provided Bacon with a model for how to subdivide natural philosophy into two distinct yet related parts. If Democritus is correct,

[124] Bacon, *Novum Organum*, in *Works*, Vol. 4, 66 (italics added); Gaukroger, *Francis Bacon and the transformation of early-modern philosophy*, 80, fn 35. That Bacon is probably criticising Paracelsus and his followers here is an interpretation also more recently supported by John Henry in his popular account of Bacon, *Knowledge is Power: How Magic, the Government and an Apocalyptic Vision Helped Francis Bacon to Create Modern Science* (London: Icon Books, 2017 [2002]), 112/208. On conflating the human and divine, also see Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', 252.

[125] See, for example, Bacon, *The Phenomena of the Universe*, in *Works*, Vol. V, 132.

[126] Bacon, *Valerius Terminus of the Interpretation of Nature*, in *Works,* Vol. 1, 83. https://en.wikisource.org/wiki/Page:The_Works_of_Francis_Bacon_(1884)_Volume_1.djvu/211. Accessed June, 2021. Space precludes going into detail on Bacon's cosmology, but for the pioneering work on this topic, see Graham Rees, 'Francis Bacon's Semi-Paracelsian Cosmology', *Ambix*, Vol. XXII, July, 1975, No. 2, 81–101. Also see Gaukroger, *Francis Bacon and the transformation of early-modern philosophy*, 175–181.

[127] For Adam as the first alchemical adept, see, for example, Roberts, *The Mirror of Alchemy,* 13.

says Bacon, that '"*the truth of nature lieth hid in certain deep mines and caves*"', and if other alchemists are also correct that 'Vulcan is a second nature, and imitateth' the effects that take nature a greater length of time to produce in the earth, then

> it were good to divide natural philosophy into the mine and the furnace: and to make two professions or occupations of natural philosophers, some to be pioneers [miners] and some smiths … namely, that these be the two parts of natural philosophy – the *inquisition of causes*, and the *production of effects*.[128]

Bacon later imports the gist of these ideas into the *New Atlantis,* where he is free to be fictive, describing both the subdivisions of labour and workplaces in Salomon's House, of which the end 'is the knowledge of Causes, and secret motions of things; and the enlarging of the bounds of Human Empire, to the effecting of all things possible', to show how such a scheme might function. 'We have three that try new experiments, such as themselves think good. These we call Pioneers or Miners' – those who in the reworked terms above are tasked with digging for causes. [129] Thus expounding upon Democritus, and agreeing also with Paracelsus on iatrochemistry, the deep mines and caves of the House's 'Lower Region' are places where all alchemical ambitions have been perfected and even surpassed, both in metallurgy and in medicine:

> we use them for all coagulations, indurations, refrigerations, and conservations of bodies … for the imitation of natural mines; and the producing also of new artificial metals … We use them also sometimes, (which may seem strange,) for curing of some diseases, and for prolongation of life …[130]

Although these ideas had little effect in Bacon's time, by the 1640s, English natural philosophers had started to practise what he had preached, and in 1667 the Royal Society of London gave Bacon centre stage as the left-

[128] Bacon, *Advancement of Learning*, 90.
[129] Bacon, *The New Atlantis*, 156, 164.
[130] Bacon, *The New Atlantis*, 156–157.

hand man of its first patron King Charles II, on the frontispiece of Thomas Sprat's *History of the Royal Society*.[131] It was with this ideal in mind that Hooke, the Society's curator of experiments, observed and experimented upon fossils, searching for their true names or characteristic marks.

### 2.3.3 Alchemical Relations between Natural Philosophy and Natural History

In the preface to the *Micrographia*, Hooke restates Bacon's mixture of religion, experimental and instrumental natural philosophy:

> By the addition of such artificial Instruments and methods, there may be … a reparation made for the mischiefs, and imperfection, mankind has drawn upon it self … whereby every man, both from a deriv'd corruption, innate and born with him, and from his breeding and converse with men, is very subject to slip into all sorts of errors.[132]

This, as shown, is the gist of Bacon's approach to alchemy. Instead of relying on the doctrine of signatures and correspondences to disclose and 'be able to call the creatures by their true names', Hooke uses 'artificial Instruments and methods', an approach promoted by Bacon as natural: 'the artificial does not differ from the natural in form or essence, but only in the efficient':[133]

> Gold is sometimes refined in the fire and sometimes found pure in the sands, nature having done the work for herself. So also the rainbow is made in the sky out of a dripping cloud; it is also made here below with a jet of water. Still therefore it is nature which governs everything.[134]

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[131] For one example of Salomon's House as the blueprint of the Royal Society, see Thomas Sprat, *The History of The Royal Society of London, For the Improving of Natural Knowledge* (London: Printed by T.R. for J. Martyn at the Bell without Temple-bar …, 1667), 151–153: 'even my Lord *Bacon*, with all his authority in the State, could never raise any *Colledge of Salomon*, but in a *Romance*' [unlike the Royal Society] (151–152). See also Michael Hunter, *The Image of Restoration Science: The Frontispiece to Thomas Sprat's History of the Royal Society (1667)* (London and New York: Routledge, 2017). According to Hunter, the frontispiece was originally intended for John Beale's *Lord Bacon's Eulogies* (another apologetic history of the Society). See also https://pictures.royalsociety.org/image-rs-3782 (accessed on the 31st of May, 2021).

[132] Hooke, *Micrographia,* preface, unpaginated. Also see Gaukroger, Francis Bacon *and the transformation of early-modern philosophy*, 127, fn 56: 'This message was not lost on Bacon's successors' (meaning Hooke).

[133] Bacon, *Advancement of Learning*, in *Works*, Vol. 4, 294.

[134] Bacon, *Advancement of Learning*, in *Works*, Vol. 4, 295.

Traditional natural historians, that is, those who write only of 'animals or plants or minerals' and omit 'all mention of the experiments or mechanical arts' have caused the 'evil' separation of art and nature.[135] In Bacon's conception – as mentioned, the 'true names' of things are physically present at the microscopic level, not on the surface, but within things themselves.

While Bacon can only imagine having access to a level of nature quite beyond the limits of the human senses, for Hooke this is a reality.[136] Further revealing himself to be Bacon's man, in his first published observation of fossils (petrified wood), '*Of* Charcoal, *or burnt* Vegetables', Hooke resounds aspects of what the caves and mines of Salomon's House are capable of, listing what he hopes one day to accomplish and show, all but paraphrasing Bacon's description of the 'Lower Region':

> the use of the Air in respiration, and for the preservation of the life, nay, for the conservation and restauration of the health and natural constitution of mankind, as well as all other aereal *animals*, as also the uses of this principle or property of the Air in chymical, mechanical, and other operations.[137]

Air is also crucial for fossil formation because Hooke's experiments evince that an absence of it is necessary for petrifaction.[138] Later, when answering objections to his conclusions on the origins of various fossils, Hooke counters that those still opposed to the empirical evidence provided by him cannot relinquish their 'prejudices' because they are possessed by '*Idola* (as my Lord *Verulam* [Bacon] says)', which prevent them from reasoning.[139] However, when it comes to fossils as objects worthy of study, Hooke and Bacon differ on what fossils are, and therefore on their epistemological value to philosophy

135 Bacon, *Advancement of Learning*, in *Works*, Vol. 4, 294.

136 Also see Gaukroger, Francis Bacon *and the transformation of early-modern philosophy,* 135: 'Like Aristotle, Bacon thinks that natural philosophy relies at the most fundamental level on a theory of matter, but whereas the potentialities and tendencies of Aristotle's physical theory seem to inhere in matter without being physically identifiable in their own right, in Bacon's account they are present at the microscopic level in a physical way'; and see Catherine Wilson, *The Visible World: Early Modern Philosophy and the Invention of the Microscope* (Princeton, 1995), especially Chapter 2.

137 Hooke, *Micrographia*, 105.

138 Hooke, *Micrographia*, 100.

139 Hooke, *Discourse of Earthquakes,* 433 (also see 332).

and natural history – the two fields entwined by Bacon's alchemy reformation.

'[F]ossils' (meaning here all things dug up), according to Bacon, are mostly 'sports of nature', of no 'serious use towards science', to be ousted from his natural history.[140] In the *New Organon*, 'natural and experimental history … is the foundation of all. We must not invent or imagine what nature does or suffers; we must discover it'.[141] Natural history is central to Bacon's reforms, so it is important to note that his definition of the term, as shown by Findlen, was a far cry from the traditional meaning (which he criticises above); instead, it was a way to 'sanitise' occult sciences like alchemy under the guise of 'natural history'. As summarised by Gaukroger, to Bacon 'natural history' was 'natural magic and alchemy relabelled'; a relabelling that helped him to 'establish a connection between his newly conceived natural history … and natural philosophy'.[142] In the *Sylva Sylvarum*, his final work, Bacon mentions that his slant is not natural history '(to speak properly)', meaning not the common definition, 'but a high kind of natural magic. For it is not a description only of nature, but a breaking of nature into great and strange works'.[143] For reasons, therefore, which stem from Bacon's problems with alchemy, the natural history of species also needs fixing. Findlen explains that Bacon excludes 'sports and frivolities of nature' (the opposite of what Hooke thinks fossils are, returning again to our common definition) from the species set because, like Paracelsian correspondences, they 'made the external appearances of nature a hieroglyph of some deeper or hidden meaning'.[144]

Hooke took Bacon seriously at every turn, and in so doing, was also not afraid to challenge him. For Hooke, as we will see, fossils were the petrified

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140 Bacon, *Novum Organum*, in *Works,* Vol. IV, 166, 166–167.

141 Francis Bacon, Lisa Jardine and Michael Silverthorne (eds), *Francis Bacon: The New Organon* (Cambridge: Cambridge University Press, 2000), 109, 19. See also Lisa Jardine, *Introduction*, in *Francis Bacon: The New Organon*, xiii.

142 Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', in Kelley (ed), *History and the Disciplines*, 239–241. Gaukroger, Francis Bacon *and the transformation of early-modern philosophy*, 195–196.

143 Bacon, *Sylva Sylavarum*, in *Works*, Vol. 2, 378; see also Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', in Kelley (ed), *History and the Disciplines*, 241.

144 Findlen, 'Francis Bacon and the Reform of Natural History in the Seventeenth Century', in Kelley (ed), *History and the Disciplines,* 252.

remains of extinct organisms or their imprints. Again, in Hooke's ontology, if a fossil represented a marine creature, it was because it had been that creature once upon a time, because it *re*-presented it as a petrifaction. For him, Bacon's claim that signatures were to be found *in* things themselves became a practical tool for fossil identification.[145] Hooke often defended this idea by referring, both implicitly and explicitly, as shown, to Bacon and his reforms, making them part of his theory and practice.

A motivation intertwined with Hooke's representation of petrifactions as rare ubiquity is his attempt to enact Bacon's alchemical reforms – thereby changing the doctrine of signatures to read the book of nature as Adam could before the Fall. Recall, Bacon argues that 'we clearly impress the stamp of our own image on the creatures and works of God, instead of carefully examining and recognizing in them the stamp of the Creator himself.' Hooke expounds that 'without inspection of the things themselves, a Man is but very little wiser or more instructed by the History, Picture, and Relations concerning Natural Bodys'; without this, a 'very imperfect Idea of the true Nature and Characteristick of the thing described' is created. Yet with 'an ocular inspection', with a 'Collection of all varieties of Natural Bodies', one 'might peruse, and turn over, and spell, and read the Book of Nature, and observe the *Orthography*, *Etymologia*, *Syntaxis*, and *Prosodia* of Natures Grammar'.[146] Namely, what Bacon calls 'true names'.

For Bacon, to read nature's book is to spell her 'words' or 'Forms' by studying how they shape matter; he uses this antique trope to discuss forms as the pinnacle of knowledge: 'invention [discovery] of Forms is of all other parts of knowledge the worthiest to be sought'.[147] While Bacon agrees with Plato, who 'did descry, *that Forms were the true object of knowledge*', he abandons him for Aristotle when accusing the former of having 'lost the real fruit of his opinion, by considering of Forms as absolutely abstracted from matter'.[148]

[145] Hooke, *Discourse of Earthquakes*, 440.
[146] Hooke, *Discourse of Earthquakes*, 338.
[147] Bacon, *Advancement of Learning*, 94.
[148] Bacon, *Advancement of Learning*, 94.

Forms, as Aristotle argued, are within things themselves, and inseparable from matter. Yet Bacon doubts whether 'it be possible' to find the compounded forms of things, explaining via analogy that the

> Forms of substances … are so perplexed, as they are not to be inquired; no more than it were either possible or to purpose to seek in gross the Forms of those sounds which make words, which by composition and transposition of letters are infinite.[149]

Nevertheless, according to Bacon, one can – as Hooke reiterated – spell out forms by reducing them to their 'simple letters' or alphabet:

> to inquire the Form of those sounds or voices which make the simple letters is easily comprehensible; and being known, induceth and manifesteth the Forms of all words, which consist and are compounded of them.[150]

For example, reducing the forms of 'an oak', or 'gold', to 'natures and qualities' such as colours, gravity and levity, density and so on (as Hooke attempted with his trials upon fossils), allows one to spell nature's words, because the letters of an alphabet 'are not many', yet are 'the essences (upheld by matter)' of which 'all creatures do consist'.[151] In this way, Bacon connects metaphysics, 'that which is abstracted and fixed' or absolute, and physics, 'that which is inherent in matter, and therefore transitory'. Physics 'inquireth and handleth the material and efficient causes'; metaphysics 'handleth the formal and final cause'; and since 'the efficient … is ever but vehiculum formae', the two, like matter and forms, are inseparable.[152]

Defining the terms in this way complemented Bacon's alchemy reformation by allowing him to maintain the old world-picture, where things were informed by their purpose, while simultaneously transferring agency from forms to their efficient causes – such as artisans or alchemists. Thus, as was also important particularly to Paracelsus, the efficient cause actuated the form inherent in matter. In doing so, Bacon did not dilute a thing's potential and

[149] Bacon, *Advancement of Learning*, 94.
[150] Bacon, *Advancement of Learning*, 95.
[151] Bacon, *Advancement of Learning*, 95.
[152] Bacon, *Advancement of Learning*, 95.

purpose; rather, he rubbed off imagined purposes and subjective meanings stamped onto things to reveal the actual purpose, which was not externally shown – a thing's 'true name'. To his mind, Bacon was changing the function of the book-of-nature metaphor; a change that throws a new light on Hooke's thoughts on names and 'the intention of Nature', with respect to fossils.[153] Bacon avers that 'if any man shall keep a continual watchful and severe eye upon action, operations, and the use of knowledge, he may advice and take notice what are the Forms'.[154] Hooke took on this responsibility, adopting Bacon's definition of forms as true names that one can potentially disclose by describing the qualities of compounded bodies and reducing them to their elements.

Indeed, Hooke introduces the *Micrographia's* reader to the idea of forms early on in observation XIV: after Bacon, Hooke believes that 'the Pyramid of natural knowledge' must 'be ascended' rung by rung to 'the knowledge of the form of bodies'; that is, 'that which the Noble *Verulam* calls *Scalam Intellectus*' put into practice.[155] Together with alleged digressions in observations XXIX and XXX, this reveals that Hooke pondered the problem of forms as early as 1665. Although he complains about lacking the leisure necessary to pursue 'speculations' on the subject, the pursuit 'to see what Information may be learn'd of the nature, or use, or virtues of bodies, by their several forms and various excellencies and properties' is 'very worth while'.[156] Again, like Bacon, Hooke equates forms with 'true names', which can only be spelled out, to borrow the metaphor, and 'found out by some such characters and notable impressions … or from divers other circumstances, as the figure, colour, place … taste, smell'. The utility of such an approach is that 'instead of studying Herbals', for example, a physician 'might have recourse to the Book of Nature it self' and therefore actual remedies. In a rhetorical move related to Hooke's preface hopes that 'artificial Instruments and methods' can cause

[153] Hooke, *Micrographia*, 155.
[154] Bacon, *Advancement of Learning*, 94.
[155] Hooke, *Micrographia*, 88, 93.
[156] Hooke, *Micrographia,* 154.

an Edenic 'reparation', therefore a move also related to Bacon's claim that the end of knowledge is to restore man's ability 'to call the creatures by their true names', Hooke speculates that Adam may have also named creatures thus:

> Who knows but *Adam* might from some such contemplation, give names to all creatures? If at least his names had any significancy in them of the creatures nature on which he impos'd it … And who knows, but the Creator may, in those characters, have written and engraven many of his most mysterious designs and counsels, and given man a capacity, which, assisted with diligence and industry, may be able to read and understand them.[157]

However, Hooke took Bacon's idea in a novel direction by adding quantitative methods to his experimental observations, as well as geometrical ideas more commonly employed by artists manipulating linear perspective.

[157] Hooke, *Micrographia*, 154.

# CHAPTER 3: SNAKE-*SHELLS*

With the idea of observing characteristics in mind, in the *Micrographia's* seventeenth observation, Hooke continues his trials on a petrified substance resembling wood. The results obtained lead him to form a working hypothesis on the process of petrifaction that includes not only vegetable but also animal fossils. In particular, Hooke focuses on "*Serpentine-stones*", nowadays commonly referred to as ammonites, using them later on in the *Discourse* to form his strongest textual and illustrative visual pair with a nautilus shell.

## 3.1 Petrifaction

After comparing the size of petrified wood's microscopic pores with those of coals, Hooke notices a second difference: the pores of petrified wood are 'fill'd up with a more duskie substance', and not 'hollow'. He weighs the petrified substance and finds that it is significantly heavier than regular wood – 'being common to water as 3 ¼ to 1'. He tests its hardness and finds it 'being very neer as hard as Flint'. He further finds that it is incombustible (unlike the *lignum fossile* in the previous observation), dissoluble, and cold to the touch, 'feeling more cold then Wood usually does, and much like other close stones and Minerals'.[158] With the results collated from these additional, exhaustive experiments and observations, Hooke is in a position to explicate the first part of his hypothesis on the process of petrifaction. Recall that at the end of the sixteenth observation, Hooke speculated that wood rotted and then 'petrify'd and turn'd into a kind of Stone, or else had its pores fill'd with certain Mineral juices, which being stayd in them … in tract of time coagulated'. Here, in the seventeenth observation, having submitted 'several pieces of very differing kinds'[159] of petrified substances to the trials listed above, Hooke concludes that 'this *petrify'd* Wood having lain in some place where it was well soak'd with

[158] Hooke, *Micrographia*, 108–109.
[159] Hooke, *Micrographia*, 107.

*petrifying* water (that is, such a water as is well *impregnated* with stony and earthy particles)' had those stony particles 'convey'd' into its pores, 'stoping them up'. This '*intrusion* of the *petrifying* particles' causes heaviness, coldness, a stonelike appearance, and all other physical properties of petrified wood.[160] Remembering once again his trials upon the *lignum fossile* from Cesi's estates, in the *Discourse* Hooke concludes that 'it seems very probable' that the petrified wood was 'first buried by some Earthquakes' and afterwards 'metamorphosed and changed by the Symptoms which usually follow Earthquakes', and which Italy is 'vexed' with: 'the emitting of hot Steams and Smoaks proceeding from subterraneous Fires'.[161]

Next, as an introduction to the second half of his petrifaction concept, Hooke states without fanfare that 'both Vegetable and Animal' bodies undergo petrifaction via the replacement of a body's usual juices with the stony solutions of petrifaction.

> Nor is Wood the onely substance that may by this kind of transformation be chang'd into stone; for I my self have seen and examin'd very many kinds of substances … both Vegetable and Animal …[162]

For example, the '*petrify'd* Shels … which are commonly call'd *Serpentine-stones*', 'found about *Keinsham*, which lies within four of five miles of *Bristol*'.[163] The locality of the petrified shells is not important here, but will be when discussing Lister's work on 'Cockle-like stones' later on.[164] Hooke notes that these shells 'are commonly thought to be Stones form'd by some extraordinary *Plastick virtue latent* in the Earth', and dismisses this more conventional idea immediately.[165]

[160] Hooke, *Micrographia*, 109.
[161] Hooke, *Discourse of Earthquakes,* 315.
[162] Hooke, *Micrographia*, 109.
[163] Hooke, *Micrographia*, 109. Hooke mentions snake-stones from Keinsham again in his first *Discourse* lecture (Hooke, *Discourse of Earthquakes*, in *Posthumous Works*, 284), and supposes that several other fossils in his possession were dug up near there, and sent by Dr John Beal. It is possible that these are the fossils that Beal brought a boxful of to a Society meeting in August 1664 (see Birch, *The History of the Royal Society of London*, Vol. 1, 457).
[164] Lister, *A Letter*, 2282.
[165] Hooke, *Micrographia*, 110.

> I cannot but think, that all these, and most other kinds of stony bodies which are found thus strangely figured, do owe their formation and figuration, not to any kind of *Plastick virtue* inherent in the earth, but to the Shells of certain Shel-fishes …[166]

Hooke's observations on snake-shells in the *Micrographia* lay the groundwork for a cluster of claims and arguments that he develops and defends in the *Discourse* lectures. As mentioned, Hooke's 'experimentum crucis' forms a part of these observations. He microscopically examines the shells' internal characteristic marks, 'boundings of certain *diaphragms*, or partitions, which seem'd to divide the cavity of the Shell into a multitude of very proportionate and regular *cells*' (recall that cells in a shell are the equivalent of pores in wood).[167] Yet although Hooke considers this to be his most crucial experiment for the identification and classing of fossils, he can do more.

Continuing his internal investigations, he notes also that some of the cavities are 'fill'd with Marle, and others with several kinds of stones, others for the most part, hollow', which leads him to speculate that 'the Shells of certain Shel-fishes' were dislocated from their usual place 'either by some Deluge, Inundation, Earthquake, or some such other means', and 'thrown', and 'fill'd with some kind of Mudd or Clay, or *petrifying* Water' that 'settled together and hardned' over time 'in those shelly moulds'. The petrified bodies under Hooke's scrutiny are traces of these earthly motions and changes, which are concreted physically within their pores and other cavities as a 'compound[ing] of several Substances:'[168]

> some parts of the same Shell may be fill'd in one place, and some other caverns in another, and others in a third, or a fourth place, or a fifth place, for so many differing substances have I found in one of these *petrify'd* Shells …[169]

Hooke postulates that these earth-shattering, sea-shifting motions, made

[166] Hooke, *Micrographia*, 111.
[167] Hooke, *Micrographia*, 111.
[168] Hooke, *Discourse of Earthquakes*, 182.
[169] Hooke, *Micrographia*, 111–112.

visible and knowable by the traces of various substances captured in petrified shells, translate the shell from place to place causing endless 'varieties'.[170] As an aside, this concept, that order is in motion and not rest, reflects the changes occurring in other areas of early modern science – notably celestial mechanics, and mathematics, which Hooke also played a significant role in developing.[171] Thus, although a fossil may appear as inert as a curio on the outside, inside it is a synecdoche of nature's dynamics and diversity, 'according as the Matter chanced to be jumbled together, and to fill up the Mould of the Shell'.[172] From his external aesthetics of chaos, Hooke orders the world internally with his novel way of thinking about, imagining, and doing Earth history.

Finally, Hooke's digging up of what his peers of the *plastick virtue* persuasion label as 'clay', his depiction and treatment of fossils as valuable and serious objects of knowledge, echoes what Eileen Reeves has claimed is a shift in perception of value from, for example, gold which is rare, to abundant stuff dug up from the earth, such as loadstones.[173] That clay both is and symbolises human flesh in the Scriptures[174] underscores a greater interest in the human and material over the divine. It also lends support to Reeves's argument that this shift in value and in values for some – an outcome of the heavens losing their place as the realm of perfect stasis, and earth no longer at the bottom of the Great Chain of Being on account of its materiality – is part of a larger discussion belonging to both astronomy and economics, which was set in motion by Copernicus's *De revolutionibus* ... For example, so far as Galileo was concerned magnets had the same value as gold to merchants, because

[170] Hooke, *Micrographia*, 111, 112.
[171] Cindy Hodoba Eric, *The Capture of Spring: Hooke's 'Vibrative Pule Communicated'* (Sydney, Australia: The University of Sydney, ses.library.usyd.edu.au, MPhil thesis, 2018); Gal and Chen-Morris, *Baroque Science*, Part II.
[172] Hooke, *Discourse of Earthquakes*, 291.
[173] Eileen Reeves, 'As Good as Gold: The Mobile Earth and Early Modern Economics' (*Journal of the Warburg and Courtauld Institutes*, 62:126–166, 1999). Reeves's great paper is about much more than I have room to indulge in here. Briefly, using a topos from economics in a cosmological debate, with Thomas More's gold chamber-pot as a conceit, she shows how and why the inversion of gold and iron mirrors the earth swapping places with the sun.
[174] Genesis, 2:7. See also Michael Ferber, *A Dictionary of Literary Symbols* (Cambridge: Cambridge University Press, 2007), 43.

the "currency" of magnets for him was determined by how much extra weight he could make an armed loadstone carry and so on.[175] Similarly, the value of fossils for Hooke is how much he can learn from them about the earth's past and so its future, 'understanding the History of the Course and Progress of Nature preceding will afford sufficient information of the Method of proceeding',[176] for as Hooke poeticises in the *Discourse*, there is scarce

> any Country in the World where these Monuments of Antiquity, these Medals of Nature, or these Sea Marks and Evidences are not to be found either above, or at some depth under Ground …[177]

As shown in the previous chapter, that Hooke finds the common more valuable than the rare is a principle that he promotes through his work. For example, in the beginning of his first *Discourse* lecture, Hooke explicitly defends the value of petrified bodies against detractors and hecklers who call them "common":

> The most part of Mankind are taken with the Prettiness or the Strangeness of the Phaenomena, and generally neglect the common and most obvious; whereas in truth, for the most part, they are the most considerable. And the greatest part of the Productions of Nature are to be seen every where, and by every one, though, for the most part, not heeded or regarded, because they are so common.[178]

In a later lecture *Of Comets and Gravity*, Hooke repeats this rant in order to defend his experiments' simplicity:

> one plain but pertinent Experiment, apply'd with Judgement, may be more significant than thousands of such as are pompous, amusing, and excite Admiration … more Discoveries in Nature may be made by the most plain, obvious and trivial Experiments to be everywhere met with, than by the far-fetcht and dear bought Experiments which some seek after.[179]

[175] Reeves, 'As Good as Gold: The Mobile Earth and Early Modern Economics'.
[176] Hooke, *Discourse of Earthquakes*, 341.
[177] Hooke, *Discourse of Earthquakes*, 341.
[178] Hooke, *Discourse of Earthquakes,* 280.
[179] Hooke, *Of Comets and Gravity*, in *Posthumous Works*, 184.

Hooke further alludes to this shift in values when he uses gold as a metaphor for fossils, in order to bolster his empirical processes against those who doubt his claims, putting an imaginary piece of gold through the same trials as he would a petrified substance, such as whether the metal resembles gold in 'Colour and Consistence', 'Specifick Gravity' and so on. Hooke argues that if the metal holds up to all scrutiny, then whether it is found on a mountaintop or in a mine,

> it may be safely concluded to be true Gold, and whoever shall deny it to be such must be looked upon as one that doth it without Reason, unless he can produce a further Criterion by which it shall be found to be very differing from it. [180]

But most importantly, as the above citation shows, fossils are a currency for Hooke because they are his primary tool for providing a causal account of how marine fossils in particular come to be on mountaintops as well as in the deepest pits of mines, in order to support his claims on earthquakes. Namely, that 'very many parts of the Surface of the Earth (not now to take notice of others) have been transform'd transpos'd and many ways alter'd since the first Creation of it'.[181]

> And that which to me seems the strongest and most cogent Argument of all is this, That at the tops of some of the highest Hills, and in the bottom of some of the deepest Mines, in the midst of the Mountains and Quarries of Stones, etc. divers Bodies have been and daily are found, that if we thoroughly examine we shall find to be real shells of Fishes ...[182]

Yet to use fossils as tools in this way, 'to deduce some Doctrine from them' on 'the Cause and Reason of the present Figure, Shape and Constitution of the Surface of the Body of the Earth',[183] Hooke needs to first convince his audience that fossils *are* 'real shells of Fishes' – a challenging task that requires him to make these similar yet different marine creatures present once more.

[180] Hooke, *Discourse of Earthquakes*, 332.
[181] Hooke, *Discourse of Earthquakes*, 317.
[182] Hooke, *Discourse of Earthquakes,* 317.
[183] Hooke, *Discourse of Earthquakes*, 334.

### 3.2 'Accidental' Anamorphosis

For all his preoccupations with making the insensible internal sensible and external, just as 'the eruption of some kind of subterraneous Fires, or Earthquakes' crack open and spew out 'great quantities of Earth', flipping them over and 'rais[ing them] above the former Level of those Parts',[184] Hooke does not neglect the telling outward details of serpentine-shells, from which he gleans the staple notion that Steno also noticed and explicated four years later in his 1669 *Prodromus*:[185] fossils are either 'the substance that had fill'd the Shell of some kind of Shel-fish' or 'the substance that had contain'd or enwrapp'd one of those Shels' – the latter an 'impression either of the inside or outside of such Shells'.[186] Recall, however, from Hooke's nautilus shell studies that external details are accidents caused by a superficies in contact with the surrounding environment. So, although external surfaces account for variety, they are not a 'Characteristick' part of any body's structure.

*Figure 3: Hans Holbein,* The Ambassadors, *1533, oil on oak.*

Nevertheless, Hooke's challenge where external appearances are concerned is to shift his audience's perception from seeing stones that mimic cockles to seeing cockles that turned into stone – either the petrified remains of marine creatures themselves or

184 Hooke, *Discourse of Earthquakes,* 291.
185 Steno, *Prodromus*.
186 Hooke, *Micrographia*, 110.

their imprints. Hooke attempts to organise and present his examinations and visual descriptions of the external parts of petrified bodies in such a way that changes how his readers imagine what they are observing, inducing a similar shift in perception to the one experienced by a moving viewer looking at an anamorphic illusion and suddenly stepping into a privileged vantage point that restores the distorted picture. For example, according to Jurgis Baltrušaitis's interpretation of the anamorphic image in Hans Holbein's well-known painting *The Ambassadors* (Figure 3), when the viewer steps into the particular vantage point desired by the painter, a picture of what may appear to be something cuttlebone-like transforms into a human skull memento mori, disrupting the apparent inertness of the image.[187] Hooke points out particular sensual details on a fossil's surface that are designed to move the reader intimately to his vantage point, restoring, for instance, 'Snake-stones' into metamorphosed snake-*shells* with repetitive, visually descriptive lists of observed similitudes and differences coupled with repetitive drawings and diagrams of the same kinds of fossils.[188] Ideally, this should serve to construct a new repository of representations in the minds of Hooke's audience, changing the way that they view and study the physical 'Repository' of fossilised bodies that he and others are in the process of collecting for the Society.[189]

In the *Micrographia*, Hooke notes that the serpentine shells are 'very different as to the manner of their outward figuration'. Most of the 'impressions' seem to be made of

> very much brused or flaw'd [shells] … but within the grain of the stone, there appear'd not the least sign of any such bruse or breaking, but onely on the very uttermost superficies.[190]

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[187] Jurgis Baltrušaitis, *Anamorphic Art,* translated by W J Strachan (California, USA: University of California, 1977), 91. For the epistemological ramifications of anamorphosis on Renaissance linear perspective and representation, see Lyle Massey, *Picturing Space, Displacing Bodies: Anamorphosis in Early Modern Theories of Perspective* (Pennsylvania, USA: Penn State University Press, 2016). For anamorphosis in general, see Martin Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat* (Connecticut, USA: Yale University Press, 1992).

[188] For example, Hooke, *Discourse of Earthquakes*, 281–284.

[189] Hooke, *Discourse of Earthquakes*, 279–280.

[190] Hooke, *Micrographia*, 110.

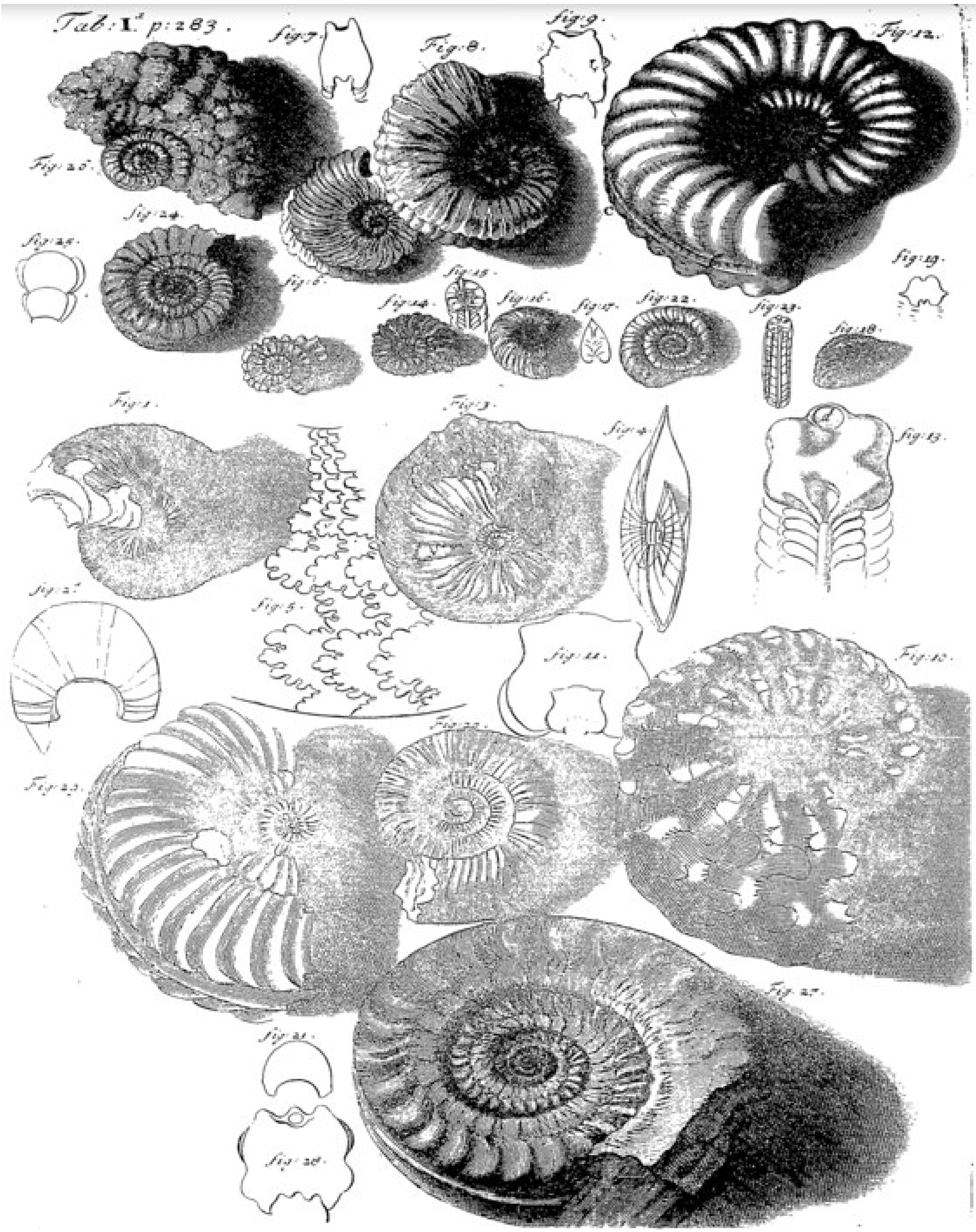

*Figure 4: 'Tab: I' in Hooke,* Discourse of Earthquakes, *in* Posthumous Works, *1705, of Hooke's drawings depicting cornua ammonis or snake-stones.*

On top of these accidents, which bruised the petrifying bodies during their hardening, Hooke observes that 'Serpentine' fossils in particular still have 'the shining or Pearl-colour'd substance of the inside of a Shel'. On some parts of a serpentine fossil the remaining shell is 'thin enough to rub off' whereas on others it is a 'thick' and 'flaky' covering – 'just like the outsides of such Shells'.[191] Here Hooke employs both the sense of sight and the sense of touch on external surfaces to persuade the reader that these petrified bodies are the exuviae of marine mollusks, combining this with his unique technique of examining both microscopic and naked-eye internal characteristics.

In a *Discourse* lecture a couple of years later, Hooke develops his lesson on the visual recognition of historical processes. He forms his strongest visual pair between a plate of '*Cornua Ammonis*' drawings (Figure 4) and their accompanying descriptions compared with drawings and descriptions of nautili shells (Figure 5):

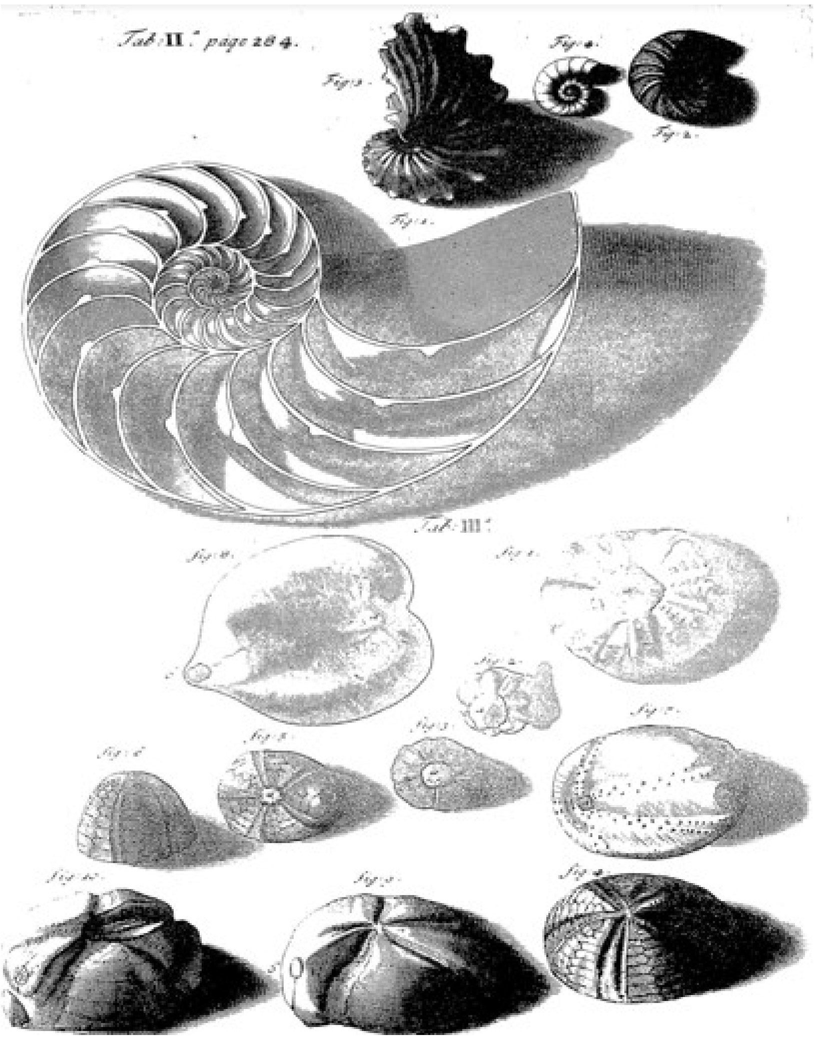

*Figure 5: 'Tab: II' in Hooke,* Discourse of Earthquakes, *in* Posthumous Works, *1705, of Hooke's drawing depicting the internal characteristics of nautili to show the similarities between nautili and ammonites.*

> I have, to parallel these Snake-stones added in Table II. a Description of three several sorts of Nautil-shells, because I had no greater variety by me, though I have seen many other kinds.[192]

To design this deliberate 'parallel', Hooke begins with his *experimentum crucis*, using characteristic marks like a grid that he can

[191] Hooke, *Micrographia*, 110.
[192] Hooke, *Discourse of Earthquakes*, 284.

superimpose over both the nautili shells and the snake-stones, revealing similitude of form even though the petrified bodies are compounded of various stony substances, and have been distorted by breaking, stopping, squeezing, and flattening. The several drawings and diagrams of snake-stones serve as a sort of stop-motion animation technique, allowing Hooke to overcome the limitations of representing them as static drawings on a page. Delving into deeper descriptive territory than in the *Micrographia*, Hooke compares the diaphragms of nautilus shells, which partition their cavities into proportionate cells, with the diaphragms of snake-stones.

> The 1st Figure represents a Nautilus shell cut *per axin*, and manifests the manner how the Diaphragms are placed in that kind of shell in the concave Part thereof; and the 2d Figure shews how they are placed up the convex side …[193]

In the first figure (‘*Fig: 1’,* Figure 5), Hooke dissects a nautilus shell ‘*per axin*’, and, just as he first accomplished with the pores of charcoal and petrified wood, turns a hidden internal characteristic into an artificial external surface – in this instance making the shell’s spiralling internal structure sensible to the naked eye. In ‘Fig: 2’, he shows how the internal structure shapes the shell’s actual external surface: ‘the wreathed [external] Lines shew where the Diaphragms join’d upon the back thereof.’[194] Moreover, to form a relation between nautilus shell diaphragms with those of so-called snake-stones, Hooke notes that ‘all of them [snake-stones] had Diaphragms or separating Valves’.[195] However, unlike ‘Fig: 2’ where nautilus shell diaphragms are visible on the external surface like construction lines, the ‘*Fimbriae* or Edges’ of a snake-stone’s diaphragms can sometimes be ‘somewhat more obscure’, yet ‘might be made apparent, by the scraping or rubbing away the outsides of them’ (‘Fig: 3’, Figure 4).[196] For example, although the snake-stone in Hooke’s

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193 Hooke, *Discourse of Earthquakes*, 284.
194 Hooke, *Discourse of Earthquakes*, 284.
195 Hooke, *Discourse of Earthquakes*, 281, 281–283.
196 Hooke, Discourse of Earthquakes, 281–282.

'First Figure ['Fig: 1', Figure 4] was much like that, of a common nautilus …'[197]

> the [petrified] Diaphragms were not smooth and plain like those of a Nautilus, but full and ruffled like the leaves of Sea-wrack … the Diaphragms were much thicker and closer together … closer, harder, and heavier.[198]

According to Hooke the snake-stone represented by 'Fig: 3' shares the structural properties of the snake-stone in 'Fig: 1' – if one imagines the first figure 'press'd quite flat; so that instead of the round Back in the 2d Figure, this ['Fig: 3'] has a Back terminated with a sharp Edge, as in the 4th Figure' (Figure 4).[199] To assist the imagination, Hooke turns to geometrical studies – specifically of the nautilus shell and snake-stone spiral.

Here he pulls out a new tool: anamorphosis. Just like the privileged vantage point in *The Ambassadors*, from which a viewer suddenly perceives a skull, in Hooke's drawing of an ammonite, the spiral's axis is the privileged vantage point. His aim is to focus on the spiral as a means to instruct his audience on how to approach the viewing of a snake-stone from the axis of its spiral in order to recognise it as a shell. All snake-stones have a 'Tapering or Pyramidal Body', which is 'coil'd up together, so that the Tip or Point of it [is] in the Center, and the Base outmost'. In 'the coiling up, the Axis of This Pyramidal Body is kept exactly in the same plane' (just as the nautilus shell's is shown to be when 'cut *per axin*'). And 'for the most part', all of the ringed ridges and furrows respect 'the Center of the Spiral'.[200] Hooke argues that these structural 'Proprieties' remain even though 'many of these Spiral Bodies [snake-stones] seem'd, as if they had been broken or shatter'd, and had grown together again in an irregular Posture'.[201] To illustrate these irregular postures of form, Hooke moves from the realistic and detailed drawings of 'Fig: 1' and 'Fig: 3' (Figure 4) to the outlines of the diaphragms and spiral in '*fig. 2*' and '*fig. 4*' (Figure 4), and flattens '*fig. 4*' by squeezing it with a grid (not shown in the

197 Hooke, *Discourse of Earthquakes*, 282.
198 Hooke, *Discourse of Earthquakes*, 282.
199 Hooke, *Discourse of Earthquakes*, 282.
200 Hooke, *Discourse of Earthquakes*, 281
201 Hooke, *Discourse of Earthquakes*, 281, 282.

drawing, but see Figure 13 in Appendix 1 for how '*fig. 4*' looks when uncompressed), using the technique of plane anamorphosis to maintain the telling physical property of keeping the 'Pyramidal Body … exactly in the same plane' despite morphological changes (Figure 5). The ontological and epistemological significance of stretching and flattening the anamorphic fourth figure to show changes in structure when the first figure hypothetically metamorphoses into the third are obvious: despite their different substances and deformities, the snake-stones have the same origin, and when juxtaposed with the shells of nautili, bear much more than a passing resemblance to them.

Moreover, by drawing and diagramming a variety of snake-stones, and describing the similarities and differences between them, Hooke overcomes the limitations of representing them as static drawings on a page. That is, the snake-stone represented by 'Fig: 3' *is like* a flattened 'Fig: 1'; but when viewed together from the first figure to the third, the triptych represents the transition of a helical shell flattening. Thus, to reverse the accidental 'anamorphosis' caused by the impact of motions and pressures in the earth on these spiral bodies over deep time, and further assist in recognising the historical process of petrifaction, Hooke draws '*fig. 4*' using plane anamorphosis, but with no particular vantage point, in order to exhibit the effects of flattening. That is, in this particular drawing, he draws attention to the plane itself.[202] In an attempt to further strengthen the visual pair of snake-stones and nautili, Hooke mentions a particular case: the '*Japan* Nautilus-shell' ('Fig. 3', Figure 5) is 'crenated on the sides, and knobbed on the back, much in the manner as several of the Snakes-stones are' – just as 'the Back of [the eighth figure of a snake-stone (Figure 4)] was gutter'd and knobbed very like a *Japan* Nautilus'.[203] Hooke focuses on the spiral throughout this *Discourse* lecture as a means to instruct his audience on how to approach the viewing of a snake-stone from the axis of its spiral in order to recognise the breakages, flattening and so on, and to *in-*

[202] Massey, *Picturing Space, Displacing Bodies* explains how anamorphosis without a privileged vantage point destroys the illusion of depth in an image by drawing attention to the finite space of the picture plane instead. See in particular 'Chapter 3. Straightening Out Anamorphosis'.
[203] Hooke, *Discourse of Earthquakes*, 284, 282.

*form* the snake-stone with the physical form of a nautilus shell, thus re-presenting it as more than just stone mimicking a fish.

## CHAPTER 4: 'FROM A DIFFERENT VIEW OF NATURE'

Although Hooke attempted to position the viewer at a privileged vantage point, many of his contemporaries remained sceptical of his causal account, despite his repeated attempts over the next thirty years to show that fossils are a single phenomenon, by drawing attention to similitudes of form and explaining away differences of substance with the mechanisms of petrifaction.[204] Most peers found his position to be a cause of anxiety, tension and ambiguity, and remained entrenched in the *lapides sui generis* hypothesis.[205] Martin Lister, a respected mineralogist and conchologist amongst other things, in a 1671 critical review of Steno's *Prodromus* (see Chapter 7), published in the *Philosophical Transactions,* declared that fossils are '*Lapides sui generis*', writing scathingly that there is no shell in shell-like fossils:

> our English Quarry-shells (to continue that abusive name) have no parts of a different Texture from the rock or quarry they are taken, that is that there is no such thing as shell in these resemblances of shells ...[206]

Lister's review, read at a Society meeting on the 2nd of November, is by extension a criticism of Hooke's work.[207] Some fellows applauded Lister's 'notions', but Hooke, present at the meeting, defended his own: 'that all those shells are the *exuvia* of animals'.[208]

By way of introduction to his review of Steno's work, Lister begins with a stipulative definition of '*Petrified Shells*': 'I mean such Shells, as I have observed in our English stone-Quarries'. Following this, he explains that his 'sentiments' about the origin of petrified shells 'are somewhat different from' Steno's,

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[204] Gal, 'Nature's Grammar', 502.
[205] Garrett, *The Routledge Companion to Eighteenth Century Philosophy*, 720. Rappaport, *When Geologists Were Historians,* 119–122.
[206] Lister, *A Letter*, 2283.
[207] Birch, *The History of the Royal Society of London*, Vol. 2, 485.
[208] Birch, *The History of the Royal Society of London*, Vol. 2, 487.

because of 'a different view of Nature'.[209] Lister has a different view of nature *literally* – a different visuality owing to his specific way of observing the natural world, which is modified by, and reflects, his developing practices as a naturalist.

By visuality, I mean the relation between an observer and the object of visual analysis, and how this object is pieced together by experimental observations that affect and alter its representation. As Robert Nelson recently explained, although "visuality" remains a problematic category, it helps to separate it as a category from "vision" (the eye as an optical instrument) in history and philosophy of science.[210] Fossils, as objects of nature *and* as cultural artefacts, are primarily analysed, constructed and represented visually. How do background knowledge, expert knowledge, and new knowledge create parallel concepts of visual meaning and modify concepts concerning cockle-shells or cockle-stones, and therefore the historicities attached to them?

## 4.1 'Cockle-like stones'

Lister's 'different view of Nature' is revealed by his preferred practical approach to solving a problem, and the similes and metaphors that he employs while describing actions and things. He claims that although 'in some Countries' one may find 'all manner of Sea shells [fossils] … *promiscuously* included in Rocks or Earth, and at good distances from the Sea,' especially along the Mediterranean, this is not the case with English fossils.[211]

> But, for our English inland Quarries, which also abound with infinite number and great varieties of shells, I am apt to think, there is no such matter, as Petrifying of Shells in the business … but that these Cockle-like stones ever were, as they are at present, *Lapides sui generis*, and never any part of an Animal.[212]

[209] Lister, *A Letter*, 2282.
[210] Robert Nelson (ed), *Visuality Before and Beyond the Renaissance, Cambridge Studies in New Art History and Criticism* (New York: Cambridge University Press, 2000), 2.
[211] Lister, *A Letter*, 2282.
[212] Lister, *A Letter,* 2282.

Lister continues to stress that he is referring *only* to 'our English' cockle stones or shells throughout his review, because the locality of the cockle stones under his scrutiny forms the first part of his supportive argument; but also to underscore his first-hand experience with these particular fossils *in situ*, and with English saltwater, freshwater and terrestrial shells in general. At the same time, Lister's adherence to English cockle stones weakens his argument because it does not allow him to move from particular to general cockle stones, so his knowledge does not and cannot account for all of them.

Lister observes that even quarries which neighbour each other yield different kinds of 'species of shells' based on substance.[213] For example,

> those Cockle stones of the Iron-stone Quarries of *Adderton* [Adwalton] in *York-shire* differ from those found in the Lead mines of the neighbouring mountains ...[214]

So that 'Iron-Stone Cockles are all Iron stone; Lime or marble all Lime-stone and Marble, [etc.]', and since the substance *is* always one kind of stone in a particular quarry, Lister places prominence on the stone shaped as a shell, not on the shell turned to stone. That different quarries yield different cockle-stones means that they are produced in situ by the surrounding stone.[215]

The second part of Lister's argument is that these cockle stones differ 'from any thing in nature besides, that either the land, salt, or fresh water doth yield us'.[216] That is, these species of cockles are unlike any species living. It makes sense to Lister that he should examine 'some of our English shores for shells, also the fresh waters and the fields', in search of 'those species of shells anywhere else, but in their respective [English] Quarries'. It makes sense that 'resemblance' is only that, because for Lister, no extinction is a premise. To underscore the impossibility of extinction, he reiterates 'that they [cockle stones] were not cast in any Animal mold, whose species or race is yet to be

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[213] Lister, *A Letter*, 2283.
[214] Lister, *A Letter*, 2283.
[215] Rappaport, *When Geologists Were Historians*, 122.
[216] Lister, *A Letter*, 2283.

found in being at this day'.[217]

Lister's notion of visual meaning is perhaps made most obvious here by his repetitive use of the word 'species', which discloses the foundations of knowledge supporting how he makes his observations, as well as underlying tensions caused by different examination techniques. Lister distinguishes the way that *he* works by describing how others *should*: 'exactly and minutely, to distinguish the several species of the things of nature' with 'heedful and accurate descriptions' and 'an attentive view'. Lister's intolerance of other ways of examining shells, such as the experimental and microscopic techniques employed by Hooke to make insensible characteristics sensible, trickles through when Lister chides 'those persons' who are 'content to acquiesce in figure, resemblance, kind, and such general notions'. And even though 'the Repository of the *R. Society* is amply furnished with things of this nature', namely also *non*-English cockle stones and so on, Lister concludes his review of Steno's *Prodromus* with a promise to send 'two or three sorts of our English Cockle-stones of different Quarries' to prove his point that English cockle-stones are only shell-like in resemblance.[218] This is a strategy intended to underscore the lines drawn by disciplinary boundaries and Lister's authority on the subject of shells. By questioning Hooke's and Steno's practices and conclusions on petrified bodies, Lister calls into question not only their ability but also their right to examine them, declaring the particularity of his expertise as a naturalist.

For example, two years later in a letter dated 12th of March 1673, '*concerning the First Part of his* Tables *of* Snails', written to Henry Oldenburg (SRS), and published in extracted form in the *Philosophical Transactions*, Lister attempted to assert his authority on cockle-stones by pointing out his expertise. By its very nature, Lister's expertise is in niche disciplines – conchology and mineralogy, here with an emphasis on English land shells – and it is his alone.

[217] Lister, *A Letter*, 2283. The myth that Lister believed in extinction seems to have, to the best of my current knowledge, been started by Charles Lyell. Lyell, *Principles of Geology*, Vol 1, (London, 1830), Chapter 3, 36. Historians who have cited Lyell on this have yet to provide evidence from Lister himself.

[218] Lister, *A Letter*, 2283.

'Again, in that Part of the Tables, you have from me, Authors are very little concern'd'. Indeed, popular interest and knowledge instigates Lister's contempt: 'in the others of *Sea-shells* and *Stone-like shells,*' he adds 'there are many Authors'.[219] In other words, Lister alone can compile 'Tables *of* Snails' to juxtapose with fossil shells.

> And I can assure you, that of near *30 Species*, I have now by me, found in this County alone, not any one can be sampled by any *Sea, Fresh Water* or *Land-Snail*, that I have, or ever saw. So that you see, I have still good Reason to doubt their Original, besides many other Arguments that my Observations about *Fossils* do afford, and which you may possibly one Day see.[220]

His authority-establishing manoeuvrers aside, Lister doubts the origin of fossil shells because he cannot identify them comparatively using any of the marine or terrestrial shells in his tables. Further, he mentions that he can demonstrate that 'there are also elegant Representations of even *Bivalve-shells*, which never owed their Original to any Animal'.[221] Finally, he promises that his completed tables will explain accompanying figures, investing them with a visual meaning constructed from his observations, with the 'Design'

> to give the Reader an exact View of Animal-shells as well as of Fossils figured like Shells, whereby he will be best able to Judge what to think of their Original.[222]

By claiming that images juxtaposing terrestrial, marine and fossil shells will enable a reader to 'Judge' what '*Fossils* figured like Shells' are, Lister is not proposing that the figures will develop the reader's visual judgement, but is ascribing to his diagrams the power of neutrality. It is a move diametrically opposed to Hooke's earlier warning against learning from finished products by

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[219] Martin Lister, *An Extract of a Letter of Mr. Martin Lister concerning the first Part of his Tables of Snails* …1673, in *Royal Society Philosophical Transactions*, Vol. 9 (London, 1674, 96.

[220] Lister, *An Extract of a Letter of Mr. Martin Lister concerning the first Part of his Tables of Snails*, 96-97.

[221] Lister, *An Extract of a Letter of Mr. Martin Lister concerning the first Part of his Tables of Snails*, 97.

[222] Lister, *An Extract of a Letter of Mr. Martin Lister* concerning the first Part of his Tables of Snails, 98. In 1678, Lister published his completed three treatises and tables in Martin Lister, *Historiae Aniumalium Angliae tres tractatus* … (London, 1678).

trusting the authority of a few pictures in books without direct experience acquired by collecting, observing and experimenting upon the bodies themselves.

Lister had already praised the value of pictures in a letter addressed to Oldenburg a couple of months before, arguing that 'Words are but ye arbitrary symboles of things', and that 'Good Design … or ye things [themselves] … would make these particulars much more intelligible and plain to you'.[223] Note that Lister's "or" is exclusive, and that Lister expects the illustrations, designed by his friend William Lodge, to be fully capable of replacing 'ye things' as static objects of visual study. In contrast, Hooke's stress on the importance of practical processes translates to his drawings of ammonites (discussed earlier): although his visual pair of ammonite and nautilus shell is comparative, his ammonite designs collectively serve to show various stages in the processes of petrifaction. But although Lister attempts to convince Oldenburg that the 'Figures' can speak objectively, and even though his remark on 'elegant Representations of even *Bivalve-shells*, which never owed their Original to any Animal' paints a veneer of intention over his figures, *he* nevertheless still has 'good Reason to doubt'.[224] His doubts about the origin of fossils had begun in his letter with Lodge's 36 drawings, which is not on shells, but on "rock-plants", published in the *Philosophical Transactions* as '*A Description of certain Stones figured like Plants, and by some Observing men esteemed to be Plants petrified*'.[225]

### 4.2 'Rock-plants'

In his letter on '*Stones figured like Plants*', Lister seems to conclude from his experiments upon and observations of 'Trochitae' and 'Entrochi' – known as Saint Cuthbert's beads in parts of England – that 'they are Parts or Pieces of

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[223] Lister, in Hall and Hall (eds and trans), *The Correspondence of Henry Oldenburg*, Vol. 10, 330.

[224] For an alternative interpretation, written within Steven Shapin's framework of the early modern English gentleman scholar, see Anna Marie Roos, *Web of Nature: Martin Lister (1639–1712), the First Arachnologist* (Leiden and Boston: Brill, 2011).

[225] Martin Lister, *A Description of certain Stones figured like Plants … 1673*, in *Royal Society Philosophical Transactions*, Vol. 8 (London, 1674), 6184. They are the fossilised stems of crinoids.

different *Species* of *rock-Plants*'.[226] Appended to Lister's published letter are annotations by his friend the naturalist John Ray (see Chapter 6), one of the 'Observing men', which Lister sent in a later letter to Oldenburg, both complimenting and complementing the former's 'accurate Observations about St. *Cutberds beads*'.[227] Remarking upon Lister's description of stones the size of walnuts which appear 'as they had been the roots of [Saint Cuthbert's beads]', Ray adds: 'Those Roots, that you have observed, are a good argument, that these Stones were originally pieces of Vegetables'.[228] Ray also postulates where the plants might grow:

> And no less wonderful, that there should not at this day be found the like vegetables growing upon the Sub-marine rocks; unless we will suppose them to grow at great depths under water.[229]

After reading Lister's account of "rock-plants" before the Society, Oldenburg sent Lister a detailed reply, informing him that his letter had been well-received by those present at the meeting, mentioning also that Hooke was particularly pleased with Lister's 'notion':

> Yr curious papers and elegant figures I produced before the R. Society, where being read and beheld with applause, and ye notion of such stones having once been plants confirm'd by divers of ye Company, and especially by Mr Hook …[230]

Although Hooke is quick to share Lister's alleged position that 'such stones' were once plants because it agrees with his own view of nature, he nevertheless does not identify with Lister's mode of perception, which will remain a cause of tension and debate between them. For example, similarly to Hooke's descriptions of fossils, Lister notes that Saint Cuthbert's beads 'are

226 Lister, *A Description of certain Stones figured like Plants*, 6184.
227 Martin Lister and John Ray, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg*, Vol. 10, 383–384.
228 Lister, *A Description of certain Stones figured like Plants*, 6186. John Ray, *A Description of certain Stones figured like Plants …*, in *Royal Society Philosophical Transactions*, Vol. 8 (London, 1674), 6191.
229 Ray, *A Description of certain Stones figured like Plants*, 6191.
230 Henry Oldenburg, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg*, Vol. 10, 363.

all broken bodies', 'depressed and crushed, as if ye joint of a hollow Cave [cane] should be trod under foot: These Crushes being also real Cracks as of a stone or glasse'. Lister also allows that the cause of these morphological changes is 'injuries they [fossils] have received in their removal, from ye natural *posture*, if not the place of their growth and formation'.[231] Yet Hooke's causal account of removal and injury is eruptions and earthquakes, and breakages may occur via mechanisms of petrifaction as well as displacement, whereas Lister's is displacement from the place of natural, spontaneous generation (owing to a plastic virtue in the surrounding stone).[232] Reiterating his argument from the *Micrographia* in his first *Discourse* lecture, Hooke counters that if fossils were 'the Product of a Plastick or Vegetative Faculty working in Stones', then they would not alter the surrounding stone, whatever its type, by stamping it with their impressions.[233] By rejecting plastic-virtue as an explanatory device for the creation of petrified bodies, Hooke challenges the notions that an object's locality determines its identity and that the earth has remained static since Creation.[234] He imagines an alternative explanation based on his own expert knowledge.

Thus, Hooke and Lister disagree on both the stuff 'figured Bodies' are made of *and* the significance of their shapes, because of their different methods of fossil observation and examination. On the one hand, as shown, Hooke can explain away shape variation by practising *his* new visual means of identification, looking through breakages and other injuries to the microscopic 'Characteristicks', making insensible marks of identification sensible. Lister, on the other hand, chooses to compare visibly identifiable anatomical parts for similitude with necessarily living beings: 'I choose this Method, as the most convincing, *viz*. to give a Comparative View'.[235] But Lister's procedures

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231 Lister, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg*, Vol. 10, 325.

232 See also Martin Lister, *A Letter of Mr. Martin Lister, containing his Observations of the* Astroites *or* Star-stones … in: *Royal Society Philosophical Transactions,* Vol. 10 (London, 1674), 277, in which Lister concludes that a relatively unbroken star-stone must have been 'preserved in its natural place'. Rappaport, *When Geologists Were Historians*, 121.

233 Hooke, *Discourse of Earthquakes*, 292, 291–292.

234 Hooke, *Discourse of Earthquakes*, 434–435.

235 Lister, *An Extract of a Letter of Mr. Martin Lister concerning the first Part of his Tables of Snails*

became a continuous cause of doubt for him when the petrified specimens under his scrutiny appeared so broken that specific parts needed for identification were missing, or failed to closely resemble those of the similar extant organism in figure and magnitude.[236] The moment Lister interpreted them as no more than nature's games via his comparative-anatomical approach, he stopped his imagination from making other connections.

Oldenburg ends his account of events at the Society meeting in his reply to Lister with this statement: 'You are pleased to call [them] *Rock-plants*, by [which] name we presume you mean *Plants petrified*, whether they grew in rocks or elsewhere'.[237] But Lister neglects to commit himself one way or another, expressing ambiguity instead:

> I have declined ye inserting any opinion concerning ye original of those stones figured like plants, because I am doubtful still. As for ye Exception of Rock plants, it might escape me; but I mean nothing more by it, than stones found in ye Rocks figured or having some common external shape like plants ...[238]

Here, attempting to avoid 'inserting any opinion' is an expression of Lister's doubt, not an attempt at either an independent or an objective point of view. His descriptions paint a particular picture of '*Rock plants*', which become more vegetable and less mineral the more he explicates them. Could everyone at the meeting have misinterpreted Lister's meaning? Perhaps Oldenburg was confused and read it wrongly. Or perhaps Ray's postscript supposition, in the *Philosophical Transactions*, that the 'plants' might be found growing in submarine depths conflated his own ideas with Lister's. Certainly something about Lister's observations contributed to everyone interpreting them as '*Plants petrified*'.

Lister's ambiguity over the origin of Saint Cuthbert's beads is genuine, and

... 9, 97.

236 See, for example, Birch, *The History of the Royal Society of London*, Vol. 4, 238: during a 1683 meeting of the Society, Lister remarks that the '[petrified] bivalve was so imperfect, as not to suffer a judgement made of it'.

237 Oldenburg, in Hall and Hall (eds), *The Correspondence of Henry Oldenburg*, Vol. 10, 364.

238 Lister, in Hall and Hall (eds), *The Correspondence of Henry Oldenburg*, Vol. 10, 368.

it comes across in his account as a shift in visuality, a blurring of the divide between stones that resemble plants versus stones that represent the plants they once were, destabilising the projected visual meaning of '*Rock-plants*' to '*Plants petrified*'. First, Lister contradicts himself by doing everything that he disparaged in his review of Steno's *Prodromus*. That is, he provides 'an account of some of the parts of certain stones figured like plants' by using descriptions of 'figure', 'size', resemblance,[239] and 'such general notions', as he referred to them depreciatively two years before. For example, Lister initially describes Saint Cuthbert's beads or 'Trochitae' thus:

> The figure of the *Trochite* is cylindrical; the outmost round or Circle … is in general smooth, both the flat-sides are thick drawn with fine and small rayes, from a certain hole in ye middle to ye circumference.[240]

But later, in the same letter that confused the Society, he shifts to botanical descriptions, divulging his morphing visuality:

> The rayes in the joynts of the branches run cross to the rayes of the stemm. On thick stems are sometimes very small branches, but mostly the bigger the stemm, the thicker the branches … The branches are known from the stemm, by being a little crooked

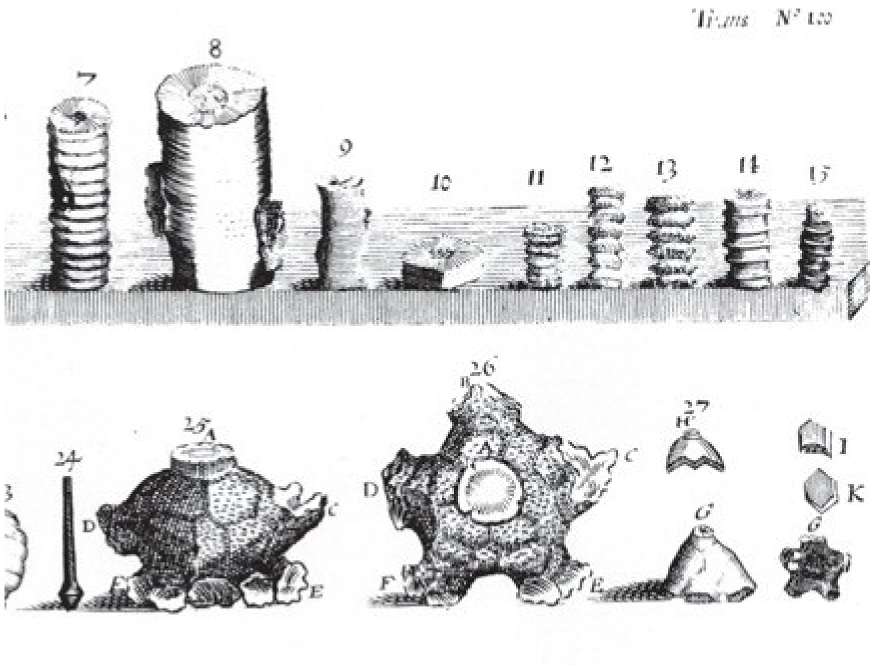


*Figure 6: A sample of William Lodge's drawings, designed to accompany Martin Lister's* A Description of certain Stones figured like Plants …, *in* Royal Society Philosophical Transactions, *Vol. 8.*

[239] Lister, *A Description of certain Stones figured like Plants,* 6181. Lister, in Hall and Hall (eds), *The Correspondence of Henry Oldenburg,* Vol. 10, 324.

[240] Lister, in Hall and Hall (eds), *The Correspondence of Henry Oldenburg,* Vol. 10, 325. Lister, *A Description of certain Stones figured like Plants*, 6184.

and something tapering or Conic.[241]

The visual move to vegetable matter is most obvious when Lister describes what he referred to in the beginning as 'the central hole' – a physical feature which gives the fossil the illustrative and colloquial name "bead" – as 'the hollows or piths' before calling them just piths. "Pith" is a deliberate word choice meant to help the reader imagine the soft cellular tissue inside the stems, and so it ensnares not only the sense of sight but also of touch.[242] As mentioned earlier, 36 figures (Figure 6) accompany Lister's letter, drawn by Lodge, which Lister explicates as though they are plants. For example, the second figure is 'A Trochites or single joint with the pith bored through, in the fashion of cinquefoil'.[243]

Lister also recounts using vinegar to dissolve fossils, but especially the calciferous coverings of trochitae and entrochi, thereby exposing their 'joynts' as well as erasing their 'seeming Suturs' and so on, and mentions that he adopted this technique from Agricola – 'Put into Vinegar (*saith he*) they buble'.[244] (Hooke also notes these 'Bubbles' in the *Micrographia* when testing the solubility of petrified wood, and explains that 'spirit of *Vinegar*' 'corrodes *corals*'.[245]) Clearly, Lister is no longer content to rely primarily on similitude of substance based on locality as he was in his review of Steno's work and English shells two years earlier, but is now also employing specific structural elements that he chooses to represent just as he uses vinegar to either delineate or erase parts. Again, his reported technical refinements reflect his developing and ambiguous notions on the origins of rock-plant fossils, which his similes, metaphors and analogies reveal. But having learnt his lesson from the

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241 Lister, *A Description of certain Stones figured like Plants*, 6186.
242 Lister, *A Description of certain Stones figured like Plants*, 6185.
243 Lister, *A Description of certain Stones figured like Plants*, 6189.
244 Lister, *A Description of certain Stones figured like Plants*, 6181, 6183. Lister is referring to Agricola's *De natura fossilium*, in which Agricola states 'Vinegar attacks some minerals such as the gem *astroites*' (location 375 of 6835) and '[Trochite] … placed in vinegar it gives off bubbles like *astroites*' (location 2117 of 6835), in Georgius Agricola, Mark Chance Brady and Jean A Bandy (eds and trans), *De natura fossilium (Textbook of minerology)* (New York: Dover Publications, 2004 [1546]).
. Lister, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg*, Vol. 10, 324, 328, 332.
245 Hooke, *Micrographia*, 108.

confusion caused by his account of rock-plants, two months later, in a letter on 'Astroites *or* star-stones',[246] Lister attempts to again strip plant-like images from his visual descriptions.[247] Here he favours figure, size, substance and so on over resemblance, and relies mainly on an artificial metaphor and quasi-geometrical descriptions to depersonalise his observations.

Rock-plants are now only 'certain stones figured like Plants',[248] and 'Astroites' are described with 'Angles', '*either* drawn out and sharp', '*or* blunt and round' (Figure 6).[249] Joints have indentations of either straight or circular lines, dependent on species. Further, some astroites or star-stones

> are distinguish't into certain Conjugations of 2, 3, or more joints: And these Conjugations are very observable in the thin-jointed stones, and are marked out with a sett of Wyers ...[250]

'Wire' is the only metaphor that Lister allows in these new observations, and he uses the image sparingly, carefully controlling it to artificialise his previously plant-like pictures. That is, 'there may be observ'd, in the deep-jointed pieces, just under the top-joint ... the *Vestigia* of certain Wyers rather than branches'.[251] In an attempt to describe the placement of these wires in relation to the rest of the structure, Lister employs one botanical analogy, stressing that it is only supposed to assist the imagination:

[246] The columnals from crinoid stems.

[247] Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones ...* in Royal Society Philosophical Transactions, Vol. 10, 274. Lister, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg,* Vol. 10, 438. Although addressed to Oldenburg, Lister's letter on astroites is probably a response to Hooke, for further in his reply to Lister's letter on rock-plants, Oldenburg also added Hooke's remark that 'he had many [of these plant-like figured stones] in ye Societies Repository, and yt he esteem'd even ye stone Astroites to have been formerly a vegetable': see Oldenburg, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg*, Vol. 10, 363.

[248] Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones,* 274.

[249] Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 275.

[250] Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 276.

[251] Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 276.

> Again, in the thin-jointed pieces there are ever five of these Wyers, or a sett of them inserted into every conjugation of joints; so that it were some representation of the thing, to imagine the stalk of *Asperula* or *Equisetum*.[252]

Then, as if attempting to distance his observation from a 'representation' reliant on vegetable matter, Lister combines illustrative analogies of flora and fauna, adding, 'Nothing that I can think of, is so like these Wyers, as the antennae of Lobsters'.[253] Even branches have become subdivisions of wires: 'some of these Wyers are knotted, and others of them fairly subdivided or branched'.[254] Yet, Lister's attempt to depersonalise his descriptions of fossils shows that his worries about observation and representation *are* personal, because as he acknowledges to Oldenburg,

> I pretend not, to discover to you their [star-stones] Original, no more than I did of the *Entrochi* … acknowledging my self at present not to be able to demonstrate (if they are not Stones of their own kind,) what they have been before petrifaction.[255]

Because of his doubt, Lister is caught between wanting to both maintain his authority as an observer and detach his observations from his alternating visuality, making them a depersonalised part of the causal process of observation. He leans towards the former want, admitting that *he* personally lacks the ability to demonstrate 'at present' whether the fossils were once living plants still extant somewhere. That he withholds belief, delegating the role of describing star-stones as actual plants petrified to a postscript by Ray,[256] just as he did in his letter on Saint Cuthbert's beads, fosters parallel concepts of visual meaning as well as differing Earth histories.

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252 Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 276.

253 Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 277.

254 Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 277.

255 Lister, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 275.

256 John Ray, A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones …, in *Royal Society Philosophical Transactions*, Vol. 10 (London, 1674), 278-279.

### 4.3 'Plants petrified'

It is obvious from Ray's remarks that he is not aware of the exchange of letters that had occurred between Lister and Oldenburg after Oldenburg's presentation of Lister's rock-plant observations. Ray still thinks that by 'rock-plants' Lister means plants petrified *not* plant-like stones – at least where Saint Cuthbert's beads are concerned:

> As for their [star-stones] *Original*, if you can allow the *Trochites* and *Entrochi* to have been fragments of Rock-plants, I see not, why you should make any difficulty of admitting these [star-stones] to have been too … only the external figure doth not correspond.[257]

According to Ray's initial comparison, 'only the external figure doth not correspond', so Lister should admit that star-stones are also plants petrified. Ray launches into an interpretation of Lister's account of star-stones that deliberately re-describes the latter's artificialised account with a bombardment of botanical language that Lister himself had favoured in his letter on Saint Cuthbert's beads.

> Your note concerning the *Wyers* springing out of the furrows or concave angles of some of the internodia, and encircling the stalk like the leaves of *asperula* or *equisetum*, was surprising, and seems to me to argue these bodies to belong to the *genus* of Vegetables, no less than Coral [etc.][258]

Ray's application of botanical descriptors as a medium for the imagination parallels Lister's 'surprising' wires and angles, changing the mode of representation of star-stones from inorganic to organic, and therefore also transforming them back to the configuration and concept of plants petrified. As Ray states, this is a comparative visual argument. He constructs it by manipulating Lister's textual images to replace them with stalks and leaves and land plants, painting a different visual meaning for the mind's eye to convince his interlocutor that 'these bodies … belong to the *genus* of Vegetables'. Ray

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[257] Ray, A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones, 278.

[258] Ray, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 278.

admits that 'no vegetable, either of Land or Sea, that I know of, hath such frequent joints [in the stalk] and short or thin *internodia*;' but this does not lead him to the *lapides sui generis* conclusion. Rather, Ray concludes that

> they are things of their own kind, whose *species* is, for ought we know, lost. If they were Vegetables, I guess they were never soft; but grew upon the rocks like Coral, and the other Stone-plants, just now mention'd; hard as they are.[259]

Several scholars have claimed that by 'lost', Ray does not mean "extinct"; he means lost in, for example, the depths of the sea – such as his earlier supposition on Saint Cuthbert's beads; this definition is Ray's notable way of working around the problem of implying imperfection in the original Creation.[260] Further, by also appealing to the senses ('I guess they were never soft; but grew upon the rocks like Coral'), Ray reifies *his* representation of star-stones. To strengthen his claim that 'these bodies' belong to 'the genus of Vegetables', he compares their external physical structure to the weed 'equisetum', because the jointed stalks of equiseta are most visually similar to the joints in the "stalks" of star-stones.[261] Finally, because Ray knows that his strategy of changing Lister's visual meaning is not enough to support and justify his claims on plants petrified, he ends his postscript on a cliff-hanger by recounting a related event from his own fieldwork and observations 'already publish'd to the world' of 'equisetum perfectly petrified'.[262]

> I have found, on the banks of the river Tanar[o] in Piedmont [NW Italy], plenty of the fragments of the stalks of equisetum perfectly petrified, with little or no increase of bulk, so exactly like that plant, that all the *striae* did all along clearly appear. The colour of these petrified stalks was white.[263]

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[259] Ray, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 278.

[260] Rappaport, *When Geologists were Historians*; Rossi, *The Dark Abyss of Time;* Rudwick, *The Meaning of Fossils*.

[261] Ray, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 278–279.

[262] Ray, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*, 279.

[263] Ray, *A Letter of Mr. Martin Lister, containing his Observations of the Astroites or Star-stones*,

Given Lister's critical remarks on Steno's Tuscan animal fossils, it is possible that Ray's perfectly petrified equiseta stalks would have moved Lister little where English rock-plants are concerned. However, Lister's ambiguity on the matter also betrays his continuing anxiety and about what these particular English fossils are. More importantly, Ray's postscript, transcribed again by Lister in his letter to Oldenburg, encourages the coexistence of dual voices on conflicting concepts of visual meaning. Their coexistence underscores that the same resource – star-stones – can be imagined and interpreted in different ways, and thus used as evidence in arguments supporting contrary claims on the history of the earth.[264]

## 4.4 Lister's sight and Hooke's touch

Nevertheless, if Lister had doubts about rock-plants, his notions on "shells" crystallised sometime between completing his tables and treatises on marine, terrestrial and fossil shells, published as *Historiae Animalium Angliae* in 1678, and his *Historiae Conchyliorum* (1685–1692), during which time his reputation as a naturalist was flourishing. On the 12th of December 1683, at a meeting of the Society, a clash between Lister and Hooke over the identity and physical makeup of some 'figured stones found at Hutton in Kent' reveals that Lister had decided to remain loyal to the *lapides sui generis* hypothesis. Here, as in his review of Steno's *Prodromus*, Lister only allows the comparison of figured stones dug up in England to extant English land- or seashells. Inspecting the 'figured stones', he declares 'the turbinates to be a stone undescribed, either by himself or Dr. Plot', and 'denie[s] any alteration, which might make them like the cochlites found in England'. That is, although Lister does 'not deny the petrifaction of [land- or sea]shells', noting that 'some petrifactions left the shell quite intire, but incrusted with stone within and without' while other 'petrifactions increase the weight of the shell', *no* processes of petrifaction

279.

264 For Lister's transcription of Ray's remarks, in his letter to Oldenburg on star-stones, see Lister, in Hall and Hall (eds.), *The Correspondence of Henry Oldenburg*, Vol. 10, 562–563.

alter a shell's shape. Rather, Lister claims that a petrified shell 'appears still the same it was formerly, without any outward alteration'.[265] Recall that, for Lister, injury to cockle-stones occurs when they are dislocated from their place of origin by art and accident; for example, the digging of a quarry. Moreover, if the sensible parts necessary for a "shell's" identification are missing, then there is not enough gross comparative-anatomical evidence from which to draw a conclusion: 'the bivalve was so imperfect, as not to suffer a judgement to be made of it'. Hooke, meanwhile, examining the very same 'stones found at Hutton', observes a similitude between them and 'petrified oisters'. But Lister, an authority on cockles, retorts that there were 'two sorts of oisters in Europe, with either of which the rock-oisters had no similitude' because they had 'no striae on the outside going from the valve to the rim'.[266] As shown, however, a retort that relies on knowledge gleaned solely at the level of the senses – such as Lister's gross anatomy – fails to impress Hooke and his instrumental means of identification, which sees through breakages, flattening and so on to 'Characteristicks'.

Moreover, in the *Micrographia's* preface, Hooke consciously conflates sight and touch by replacing both senses with a microscope: 'the roughness and smoothness of a Body is made much more sensible by the help of a Microscope then by the most tender and delicate Hand'.[267] The microscope, for Hooke, is no longer strictly an optical instrument: it also creates a new hybrid sense of optical touch. This kind of instrumentalised touch comes to the fore when considering, again, that to Hooke fossils are either re-presentations or imprints. Knowledge of the former relies predominantly on the sense of microscopic sight, on pattern recognition between, for example, an ammonite and a nautilus shell. The latter relies on intimate and prolonged contact – on a trace of a particular past – created when the petrified body stamped itself into the softer surrounding surface, which also hardened around it over time. In this way, the sense of touch has an in-built component of temporality, which is

[265] Birch, *The History of the Royal Society of London*, Vol. 4, 238.
[266] Birch, *The History of the Royal Society of London*, Vol. 4, 238.
[267] Hooke, *Micrographia*, Preface, 114. See also Hodoba Eric, *The Capture of Spring*, 66.

missing from Lister's (and Plot's) static *lapides sui generis* shells.

Therefore, in the dispute over the 'figured stones found at Hutton in Kent', when Lister observes selenite encrusting the outside of a 'figured stone', and Hooke, examining the same 'stone', observes shell, the 'stone' that each man perceives is so different not only because of *lapides sui generis* versus organic origins tensions, much less so by vision (in the sense of the surface texture of the stone created by light reflecting off it and falling onto the retina), but different visualities.[268] Hooke's is a visuality caused by radically instrumentalised and hybridised senses, which change not only his practices of experimental observation, but also his perception of Earth history.

Now, the 'Dr. Plot' whom Lister references as an authority on fossils is his friend Robert Plot, introduced earlier as the first keeper of the Ashmolean Museum. Plot was already a propellent proponent of the *lapides sui generis* hypothesis in 1683, and had given Lister permission to recycle twenty engravings of fossilised marine mollusks from his 1677 *The Natural History of Oxford-shire* for the latter's *Historiae Animalium*.[269] In his published work, Plot objected openly to Hooke's conjectures on fossils and changes to the earth's superficies. More so than Lister, Plot's objections, and his work on fossils, bring the opposing background beliefs and metaphysical assumptions only hinted at thus far to the fore. These assumptions and beliefs affect visuality, and are therefore crucial to the interpretation of stones or shells as objects that provide evidence on one type of Earth historicity or another.

[268] Birch, *The History of the Royal Society of London*, Vol. 4, 238.
[269] Roos, *Web of Nature*, 179.

# CHAPTER 5: 'VERY DEFICIENT IN NATURAL HISTORY'

There are three parts to the early modern fossils puzzle. The first is whether fossils are the remains of living things and their imprints; the second, whether those living things are extant somewhere or extinct; the third, if they are the remains of once living animals and plants, how were they dislocated from their 'natural place'. As mentioned, Hooke's dogged persistence in pursuing and re-presenting petrified bodies was further motivated by his need to provide a causal account of how marine fossils in particular came to be on mountaintops as well as in the deepest pits of mines, in order to support his claims on earthquakes and subterraneous eruptions. Scholars have noted that in England, Lister, Plot, and Edward Lhywd (for a spell), pushed for the *lapides sui generis* hypothesis to prevail; whereas Hooke, Ray and John Woodward espoused the organic origin of fossils.[270] Yet, at various points in their careers, both Lhywd and Ray attempted to maintain both positions for similar reasons (see Chapter 6). And of the latter group, Hooke was the only one to claim radically that fossils are the remains of once living beings that have become extinct. Of the former group, Lister and Plot in particular objected vehemently to Hooke's arguments on earthquakes and subterraneous eruptions as transporters of fossils. Plot argued that if such momentous events had occurred, then they would have been documented by ancient sources, and since they had not been documented, they had not happened.[271] And the implicit premise in all of Lister's arguments, from the very beginning, with his critical review of Steno's *Prodromus*, is that extinction implies, as Martin Rudwick put it, 'some imperfection and incompleteness in the design of the original

[270] Stephen Jay Gould, 'Chapter 9: Father Athanasius on the Isthmus of a Middle State: Understanding Kircher's Paleontology', in Paula Findlen (ed), *Athanasius Kircher: The Last Man Who Knew Everything* (Place Unknown: Routledge, 2004), 214. Rappaport, *When Geologists Were Historians*, 121–122. Rudwick, *The Meaning of Fossils*, location 1108–1114. See also Edward Lhwyd's biographical sketch of Robert Plot, in Robert Plot, *The Natural History of Oxford-shire* (Oxford: Printed at the theater, 1706, second edition [1677]).

[271] Plot, *The Natural History of Oxford-shire*, 113–144. Rappaport, *When Geologists Were Historians*, 122.

Creation'.[272] My aim here is not to analyse the 'controversie', but to delve deeper into how and why the same resources can be used to construct two opposing images of nature and therefore contingent histories owing to contrary motivations as well as practical and theoretical knowledge-making practices that train the imagination.

Hooke had already proposed extinction in the *Micrographia* – but the importance of extinction for Hooke lies less in extinction itself and more in what it implies about the natural history of the earth as a physical body, a *planet*. Namely, the earth's internal motions and surface changes through time, and that the geological present can provide evidence about the earth's past. What unimaginable juggernauts are necessary to level and raise mountains, to hurl and bury seas, and hence destroy species? Hooke's observations, experiments and attempts to construct a theoretical framework based on spatial and temporal considerations by studying fossils not as objects of mimesis but as *traces* of the earth's changes provide support for his concept that the key to understanding variety and order rests in motion.[273] In this new practice of observation, fossils are paradoxically a synecdoche of nature's diversity and dynamics, which can be used to construct a natural history of the earth from the earth.

### 5.1 'Lost'

At the end of his first *Discourse* lecture in 1668, Hooke posits that 'there may have been divers Species of things wholly destroyed and annihilated, and divers others changed and varied'. 'And this,' he announces to his audience, 'I imagine to be the reason why we now find the Shells of divers Fishes Petrify'd in Stone, of which we now have none of the same kind'.[274] Hooke's account of how fossils 'came to be disposed'[275] is grounded in natural, physical processes – changes in the earth and its superficies *not* caused by human

[272] Rudwick, *The Meaning of Fossils,* location 1157.
[273] Gal, 'Nature's Grammar'. Gal and Chen-Morris, *Baroque Science*, Part II.
[274] Hooke, *Discourse of Earthquakes*, 327.
[275] Hooke, *Discourse of Earthquakes*, 332.

manipulations of art, but by earthquakes and subterraneous eruptions, and hence also *not* a civil history. Nine years later, Plot would 'engage in this great controversie' with a long chapter on all things dug up from the earth in *The Natural History of Oxford-shire* (1677), in which he would form a 'deliberate rejection' of Hooke's claims, reinforced by his *The Natural History of Stafford-shire* (1686).[276] Two years after *Stafford-shire*,[277] Hooke would defend his ideas on earthquakes and fossils against Plot's objections in a series of *Discourse* lectures. Juxtaposing Plot's 'synchronic, symbolical' relations with Hooke's 'causal, diachronic' ones[278] reveals that the first image is of fossils as static resemblances; the second, as explicated previously, is a stop-motion picture of fossils as re-presentations: not resemblances, but the things themselves present again. Thus I advocate Paolo Rossi's claim that of these two images, only in the second one is nature 'no longer opposed … to history, which is the reign of becoming and change'.[279]

In chapter one of his *Oxford-shire*, Plot explains that he 'shall consider first, Natural Things, such as either [nature] hath retained the same from the beginning, or freely produces in her ordinary course; as Animals, Plants, and the *universal furniture of the World*'.[280] That he defines 'Natural Things' as things that nature has 'retained the same from the beginning' is key to understanding his 'reasons' in the fifth chapter 'Of formed Stones' for supporting Lister's conclusion that stones resembling animals are *'Lapides sui generis'* and not *'formed in an Animal* mould' (that is, literally not formed by or from any part of an actual organism).[281] For both Lister and Plot extinction is not a premise because it simply cannot be assumed. This is not surprising – biblical literacy infused the culture of Reformation England, playing pivotal roles in, for

[276] Plot, *The Natural History of Oxford-shire,* 103, 121; Robert Plot, *The Natural History of Stafford-shire* (Oxford: Printed at the theater, 1686), 52, 176, 176–198.
[277] Henceforth I'll refer to the first as *Oxford-shire* and to the second as *Stafford-shire* to prevent confusion between the two works.
[278] Gal, 'Nature's Grammar', 504.
[279] Rossi, *The Dark Abyss of Time*, 4.
[280] Plot, *The Natural History of Oxford-shire*, 1.
[281] Plot, *The Natural History of Oxford-shire*, 114, 112. For Plot citing Lister's review of Steno's *Prodromus*, see also page 103.

example, shaping intellectual and political strivings and worries.[282] By deploying commonplace exegesis as part of his argumentative strategy, Plot waves an admonitory finger at Steno and Ray, though at Hooke in particular, citing the *Micrographia's* seventeenth observation '*Of* Petrify'd wood *and other* Petrify'd bodies' prolifically, and warning that the stones 'resemble no species of shell-fish now to be found'. It seems unimaginable to Plot that 'these Species may be now lost' because '*Providence* which took so much care to secure the *works* of Creation in *Noah's Flood*' would not 'suffer any one *species* to be lost' (see 6.1 For Hooke's response to Plot).[283] Moreover, because 'Natural Things' possess the property of constancy-since-Creation, Plot attributes all changes to human hands and art. The reason that most fossils are 'injured' is not due to the natural processes by which Hooke explains their very creation from living beings; for Plot the damage is caused, just as it is for Lister, 'in digging *cellars, foundations,* etc.' Thus, although semi-petrified shells are not the same as formed stones, Plot can also explain away why parts of 'oyster' shells are found on mountains and in the strata of an 'in-land County'. He imagines that perhaps past inhabitants ate shell-fish and made a midden in an area of earth plentiful with petrifying juices. For larger areas, he hypothesises that invading navies may have had a supply of oysters for food, dropping the remains as they crossed in-land.[284] In any case, this is speculative civil history employed on a big scale to support the sacred history of the earth, not a history of the earth from the earth itself.

In response to Steno's supposition (Chapter 7) that Noah's flood was responsible for depositing marine life on mountaintops and so on, and Ray's supposition that the flood 'proceeded from *Rain*', Plot points out that floods

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[282] Kevin Killeen, *The Political Bible in Early Modern England* (Cambridge, UK: Cambridge University Press, 2017). As Keller has shown, a similar debate on the Continent was whether the plant silphion was extinct or lost, with historical figures relying on both numismatic and empirical evidence: Keller, 'Nero and the Last Stalk of *Silphion*: Collecting Extinct Nature in Early Modern Europe', 429–436.

[283] Plot, *The Natural History of Oxford-shire*, 114–115. For Hooke's detailed response to this objection by Plot, see Hooke, *Discourse*, 433–435, but especially page 435 where Hooke says what he really means.

[284] Plot, *The Natural History of Oxford-shire*, 118–119.

typically wash things downhill, and discounts all deluges as 'nothing more improbable'.[285] That "shells" were *not* dumped onto mountaintops by Noah's flood is the only point of agreement between Plot and Hooke – the latter concluding that it is 'very improbable that these Shells should have been the effect of *Noah's* Flood by reason of its short duration'.[286] Plot argues that, first, the flood in Noah's time 'at most … covered only the *continent* of *Asia* [and not the] uninhabited *Western* part of the World'; second, it 'remained on the Earth but *forty natural days*, too small a time for so many shell-fish, so dispersed, as they must be presumed, to be by so violent a motion'; and third,

> why should we think that any *shell-fish*, especially of the *testaceous* kind, whereof there are some that always stick to rocks, and others that have no locomotion, as *Oysters, Muscles, etc.* but what is given them by the *Waters* violence, should leave their beds in the Sea at all, and be carried aloft to the tops of *Mountains.*[287]

For the region destroyed by Noah's flood, Plot references the Protestant theologian Edward Stillingfleet's 1662 *Origines Sacrae ('Vide* Stillingfleti *Origines Sacras, lib*. 3. *cap.* 4'*)*; and for the duration of the deluge, *Genesis*.[288] The region cited by Plot – 'only the *continent* of *Asia'* – seems like heresy, and so offers an excellent example of early modern exegesis of sacred history as well as how it was used in natural philosophy. Although in *Genesis* it states 'the Waters prevailed exceedingly upon the earth, and *all* the high hils, that were under the *whole* heaven were covered', and 'Fifteene cubits upward, did the waters prevaile; and the mountaines were covered',[289] as Rhoda Rappaport

[285] Plot, *The Natural History of Oxford-shire*, 112. Steno, *Prodromus,* 89–90, Ray, *Observations topographical, moral, and physiological*, 125–126.

[286] Hooke, *Discourse of Earthquakes*, 408.

[287] Plot, *The Natural History of Oxford-shire*, 112. It is unclear from where Stillingfleet obtained his information here; see *Genesis* 7.19 for a refutation of his statement.

[288] Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370–373.

[289] *Genesis,* 7:19, 20. (Stillingfleet and I cite the 1611 KJV.) According to Mark H Stone, in 'The Cubit: A History and Measurement Commentary', *Journal of Anthropology*, 2014(2, article 37):1-11, the cubit in the Scriptures has two possible dimensions: either the 'short cubit', or the 'ong cubit'. The latter cubit dimension is usually taken to mean from 'the elbow to the tip of the middle finger' (1), approximately a mean of '18 inches' (10), though these dimensions did not become a standardised unit of measure until after Greek and Roman conquests, and thus varied depending on location and period (1–10). Plot was also no stranger to deviating

and, more recently, Kevin Killeen have explicated, the Bible was open to malleable interpretation – such as Baruch Spinoza's, which highlighted 'biblical inconsistencies',[290] to put it mildly.[291] According to Rappaport, regardless of the predominantly hostile reception received by Spinoza's *Tractatus theologico-politicus* (1670), one reason amongst many being 'Spinoza's denial of Mosaic authorship of the Pentateuch', which outraged Stillingfleet, Spinoza succeeded in calling into question scriptural interpretation, and thus brought vividly to attention 'the need for a scholarly approach'.[292] However, this need had already started to grow in the first half of the seventeenth century alongside the rise in popularity of mathematics over the historical sciences. The former was praised for the certainty of its irrefutable proofs, whereas the latter, like geology, were lamented for their probabilistic, provisional conclusions.[293]

It comes as no surprise, then, that Stillingfleet subtitles his work as 'a *rational account* of the grounds of natural and reveal'd religion' (note his italics). He explains that the veridicality of the flood account has come under question for two reasons that seem '*repugnant to Reason*': first, because the amount of water available on the earth is not enough to cause and sustain such a titanic deluge; and second, because the ark's '*capacity*' seems not up to the task of '*preserving all kinds of Animals*'.[294] In preparation for his interpretation and defence of the flood account, concerning the amount of water, Stillingfleet notes two objections. First, even if 'all the Water which is contain'd in the Air, supposing it to fall down, should raise the surface of Water upon the Earth', it would only 'raise' it to 'a foot and a half in height [approximately 1 long cubit]'.[295] Therefore,

dimensions: in his *of Oxford-shire* epistle to the reader, he complains about the many dimensions for the mile in Oxford-shire alone. See also Hooke, *Discourse of Earthquakes*, 407, for a conversion factor from cubits to feet. Italics added.

290 Killeen, *The Political Bible in Early Modern England*, 43.

291 Killeen, *The Political Bible in Early Modern England*. Rappaport, *When Geologists Were Historians*, Chapters 2–3.

292 Rappaport, *When Geologists Were Historians*, 73–76.

293 Rappaport, *When Geologists Were Historians,* Chapter 3. Killeen, *The Political Bible in Early Modern England*, 42-45, 69-70.

294 Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370.

295 Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370.

> either new Waters must be created to overflow the Earth, or else there must be suppos'd a Rarefaction of the Water contain'd in the Sea and all Rivers, so that it must take up at least fifteen times the space that now it doth …[296]

Second, supposing that 'the Water had been thus rarefy'd,' then it 'could neither have destroy'd Man nor Beast, neither could *Noah's* Ark have been born up by it any more than by liquid Air'.[297]

In order to both defend Noah's flood and keep it within the realm of possibility allowed by nature, Stillingfleet needs to minimise the area covered by the available water, thereby allowing the floodwater to reach the height given in *Genesis*. He claims: 'I cannot see any urgent necessity from the Scripture to assert, that the Flood did spread it self over all the surface of the Earth.'[298] By refuting the flood's universality, and shrinking the area submerged, he interprets the flood as 'universal … to Mankind', *not* universal to 'the Globe of the Earth, unless it be sufficiently prov'd that the whole Earth was Peopled before the Flood'.[299]

Yet, when it comes to specifying a particular region for the flood, or what Plot refers to as a '*National* Flood', Stillingfleet limits himself to a couple of vague conjectures. For example, it could not be 'so small a Country as *Palestine* … as some have ridiculously imagin'd', so 'suppose then the whole Continent of *Asia* was Peopled before the Flood, which is as much as we may in reason suppose'. When paraphrasing Stillingfleet, Plot throws Stillingfleet's cautious suppositional tone to the wind and states that the flood 'at most … covered only the *continent* of *Asia*'.[300]

Moreover, Plot argues that if the deluge *had* been universal, thus stranding shellfish on mountaintops, such violent motions of massive bodies of water would have carried *all* shellfish,

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[296] Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370.
[297] Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370.
[298] Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370.
[299] Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370.
[300] Plot, *The Natural History of Oxford-shire*, 112; Stillingfleet, *Origines Sacrae*, Book III, Chap. IV, III, 370–371.

> such as *Crabs, Congers, Lobsters*, etc. which last having *locomotion*, I should much rather expected to have found *petrified* on tops of Mountains, than any of the *testaceous* kind, and yet *these* we meet the fewest of any.[301]

That is, although '*Lobsters'* have 'locomotion', for '*Oysters, Muscles'* and so on to be dislocated and transported from their reefs, the motion would have to be so violent as to break rock. But as mentioned earlier, Plot does not permit catastrophic events into his account of the origin of formed stones, because there is no record of them in human history.

Attacking Hooke's *Discourse* lectures directly, Plot supposes for the sake of argument that even if a flood had covered England for 'hundreds of years', 'of which there is no Record deliver'd to posterity', it is hard to imagine that it covered 'the highest Hills', or that it could 'force the *shells* to their tops, which are weighty and rather affect the lowest places'.[302] Reading the present into the past, for Plot it is equally unimaginable 'that the Mountains … were heretofore low places and since raised by *Earth-quakes*', especially because earthquakes experienced in the 'Northern parts' of England 'are so inconsiderable, that they scarce sometimes are perceived',[303]

> unless we shall groundlessly grant, that in the infancy of the *World* the *Earth* suffered more concussions, and consequently more mutations in its *superficies*, than it has done ever since the Records of time.[304]

Therefore, the silence on natural catastrophes in *human* history, coupled with his preferred interpretation of *sacred* history, brings Plot to his greatest objections to Hooke's notions on the *natural* history of the earth – specifically the effect of the earth's internal motions upon its superficies. Namely against Hooke's claim that these internal motions

> sometimes raise Mountains, Hills, Islands, etc. and sometimes produce the quite contrary Effects, by leveling of Eminences of sinking of Places,

[301] Plot, *The Natural History of Oxford-shire*, 114.
[302] Plot, *The Natural History of Oxford-shire*, 113.
[303] Plot, *The Natural History of Oxford-shire*, 113.
[304] Plot, *The Natural History of Oxford-shire*, 113.

> swallowing up Rivers, and making Lakes of Land, or sinking Lands under the Sea, and the like.[305]

Now, Plot acknowledges that if he is going to reject the hypotheses of Hooke, Ray, Steno and others, then he also needs to provide 'a much higher principle for [the] efformation'[306] of formed stones. He states that if the origin of crystals is attributed to 'some latent *plastick power* of the *Earth*', then there is no reason to differentiate between crystals and other fossils, as both Hooke and Steno do.[307] That Plot rejects the proposed distinction between inorganic and organic fossils helps his argument in two ways. First, if all fossils are inorganic, then there is no need to abandon the *Lapides sui generis* hypothesis. Second, it paves the way for a 'much higher principle', with the power of simplicity, capable of explaining the formation of all fossils. Thus, according to Plot, whose 'principle' is contingent upon his background knowledge as a naturalist and a chemist, *all* fossils are formed from this plastic virtue by crystallisation.[308]

Further, he is aware that an argument supported by exegesis and an absence of evidence from human history is wobbly at best, for he is quick to assure Hooke and Ray that he is engaging them on their own terms: 'according to the wishes and advice of those Eminent *Virtuosi*, Mr. *Hook* and Mr. *Ray*', Plot has 'made some considerable collections of these kind of *things* [fossils], and observed many particulars and circumstances concerning them'.[309] But the way in which he orders his observations and descriptions throughout *Oxford-shire* is not novel. He employs a static taxonomy, classifying 'formed stones' based on symbolical correspondences – more akin to the alchemical tradition that Bacon wanted to sanitise by ridding it of such correspondences (Chapter 2) – in a manner structured to support his claim that the earth has remained unchanged 'from the beginning'.

[305] Hooke, *Discourse of Earthquakes*, 416.
[306] Plot, *The Natural History of Oxford-shire*, 98.
[307] Plot, *The Natural History of Oxford-shire*, 115.
[308] Plot, *The Natural History of Oxford-shire*, 122.
[309] Plot, *The Natural History of Oxford-shire*, 111.

'I shall … first treat of such *formed stones* as either in name, or thing, or both, relate to the *Heavenly Bodies* or *Air*'. After the heavens and air, Plot forms relations of 'name, thing, or both' between fossils and the '*Watery Kingdom*', then 'such as resemble *Plants* and *Animals*, whether in the whole, or parts', and finally, fossils that seem to 'imitate *Art*'.[310] So, for example, Plot places the star-stones previously discussed '[a]mongst the *stones* that have relation to the *Heavenly Bodies*' because they resemble stars in both name and shape.[311] Yet in the chapter 'Of Formed Stones', Plot's symbolically mediated correspondences are primarily designed to comparatively and visually show Hooke and others of the '*Animal mould'* persuasion that animal fossils are stones resembling the animal, 'but in *figure* only'.[312] In other words, what Hooke perceives as nature's re-presentation is nature's mimesis.

Employing comparative-anatomical techniques in the style of Lister, Plot makes observations of the shape, place and posture of formed stones to lure his readers to Lister's *Lapides sui generis* 'opinion'.[313] For example, to show that stones shaped like 'sea-fishes' are not 'the spoils of real Fishes', Plot favours two naked-eye observations that he keeps pointing out throughout the chapter.[314] The first is that the formed stones under his scrutiny *do not differ* 'at all from that in the [rock] bed wherein they lye, and out of which they seem to be formed'; the second is that they *do differ* from all the shells that they resemble, whether from illustrations 'in Books,' or that Plot has 'seen in collections of that sort of Shell-fish'.[315] Owing to these observations, Plot argues that similitude is a weak foundation upon which to construct a principle on the origin of formed stones.[316] For a formed stone to *represent* the animal that it resembles, according to Plot, it would have to be a perfect form of the "real" animal. Considering his anxieties about extinction and other implied imperfections in

[310] Plot, *The Natural History of Oxford-shire*, 80.
[311] Plot, *The Natural History of Oxford-shire*, 81.
[312] Plot, *The Natural History of Oxford-shire*, 102.
[313] Plot, *The Natural History of Oxford-shire*, 118.
[314] Plot, *The Natural History of Oxford-shire*, 98.
[315] Plot, *The Natural History of Oxford-shire*, 102.
[316] Plot, *The Natural History of Oxford-shire*, 120.

the original Creation, it follows that any imperfect or distorted object could not be a representation of the "real" animal, because it could not have been formed in a literal 'animal mould'.

Examining a 'streaked *Cockle stone*', Plot makes comparisons with the 'real *shell-fish* … called *Conchylia striata*', and upon the authority of the Italian naturalist Ulisse Aldrovandi's (1522–1605) [317] observation that the real '*Conchylia striata*' is 'plain and smooth within', he illustrates that this is 'contrary to what we find in' streaked cockle stones, 'as is shewn by *Fig*. 16' (Figure 7).[318]

> [Fig. 16.] shews the in-side of one of those stones, not only lineated from the *commissure* to the *rim*, but adorned also with four or five transverse *fillets*, not made of *one*, but several conjoined *lines*, which seems also to conclude it to be *Lapides sui generis*, and not to have been molded by a striated *Cockel-shell*.[319]

The streaked cockle stone only resembles the streaked cockle shell, and so Plot concludes resemblance and '*Lapides sui generis*'. This is

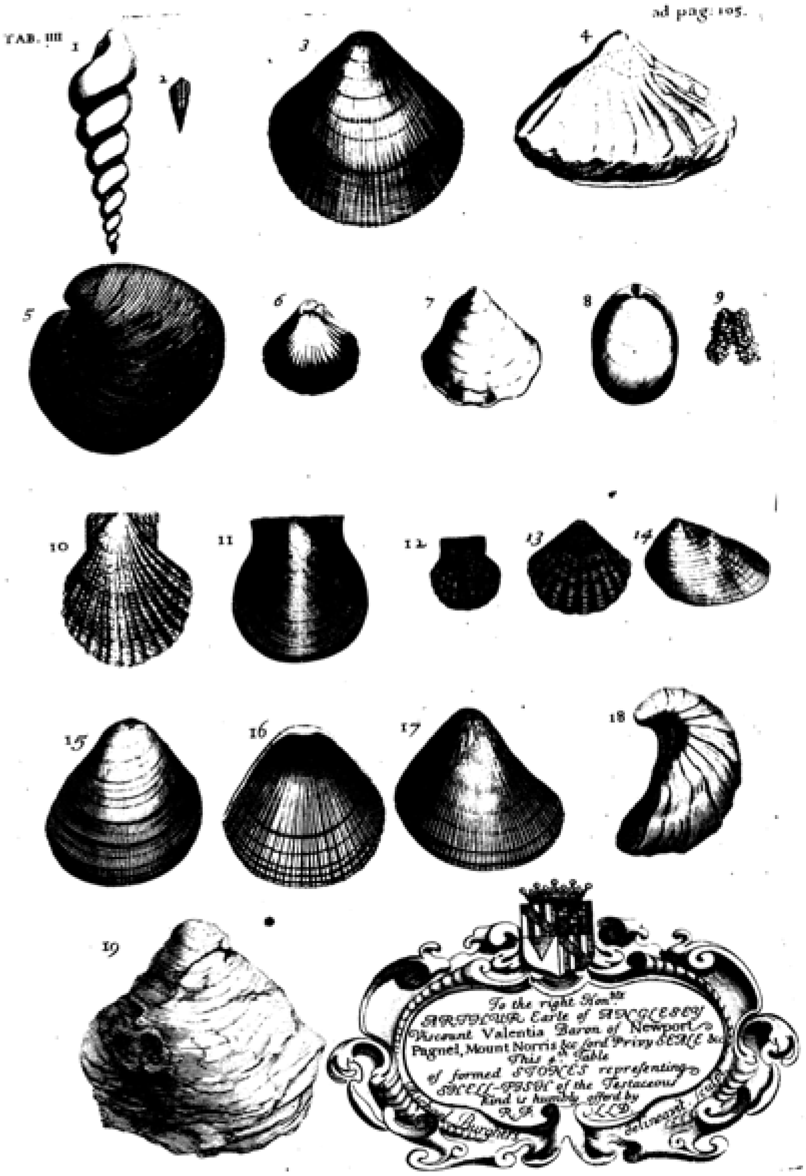


*Figure 7: Tab. IV from Robert Plot's* The History of Oxford-shire. *The striations on the inside of figure 16 show, according to Plot, that this shell is lapides sui generis.*

[317] Plot, *The Natural History of Oxford-shire*, 104.
[318] Plot, *The Natural History of Oxford-shire*, 104.
[319] Plot, *The Natural History of Oxford-shire*, 104–105.

because, contrary to Hooke, who posits that 'divers Species' have been 'destroyed, and divers others changed and varied' owing to the earth's physical changes, Plot cannot and more to the point *will not* imagine extinction and variance of species. It points to an important and interesting difference about the utility of fossils for Lister and Hooke, based on their divergent definitions of what a fossil *is*, and in doing so reveals why Plot's *Oxford-shire*, for example, is an ahistorical account of nature.

What a fossil is defined as consequently defines its epistemological significance. Although Plot expresses ambiguity over the purpose of nature's mimesis – his teleological explanations are that formed stones either exist for man's '*admiration*', or the purpose they serve remains unknown[320] – as shown, he defends his and Lister's belief that the earth's superficies has not been altered significantly by physical processes since the original Creation. Thus, he argues that marine *life-like stones* are found on mountaintops, and that particular fossils are found in specific strata, because it is where they were generated in situ.[321] Plot's adoption of the ontology of fossils as formed stones agrees with his epistemological need to show that the earth's superficies has remained unchanged. As previously discussed, the only disruptions that move marine life to mountaintops are attributed to human hands and art, and thus civil history is enforced upon nature to explain away strange and estranging spatio-temporal changes and disruptions. Indeed, in his *Stafford-shire*, Plot goes so far as to claim that since 'ancient *Medalls* … *Pavements, Urns, Monuments of Stone, Fortifications,* etc' are 'all made and fashioned out of *Natural* things, [they] may as well be brought under a *Natural History* as any thing of *Art*' – though he concedes it may seem 'to some altogether forraigne to the purpose'.[322] On Plot's placement '*Of Antiquities*' into the category of '*Natural History*', Rappaport remarks, 'That objects were made of natural materials seems peculiarly idiosyncratic as a rationale', before delving into an explanation about his use of 'Monuments'; but she glosses over the problem

[320] Plot, *The Natural History of Oxford-shire*, 69, 80, 121–122.
[321] See also Rappaport, *When Geologists Were Historians*, 106.
[322] Plot, *The Natural History of Stafford-shire*, 392.

pointed out by Plot himself – manmade objects are foreign to a work on '*Natural History*'.[323] Namely, Plot is aware that the two do not cohere. But this is not a category mistake. Rather, it is a deliberate smudging of the lines between civil and natural history to use the former in place of the latter, and it instigated Hooke to present a systematic defence against all of Plot's objections, in which he would invert Plot's use of antiquities and art (see 5.2). Although Hooke had used antiquities as a metaphor for how fossils could be studied and read as documents of the past in 1688, for Plot, "Figured stones" cannot be studied like urns or read like medals and monuments – they are objects of nature whose purpose remains dubious. And although this static definition of fossils would enable Lister, who had described and classified them with his 'Tables', to use the correlation between 'Cockle-like stones' and rock to follow and map rock and soil beds across England,[324] it would also fail to capture fossils as traces of a natural history of the earth's past. To do so would necessitate contradicting the accounts of Creation given in *Genesis* – a price that Plot and Lister could not imagine paying, even though Plot, for example, was willing to compromise when it came to the region of Noah's flood. Recall that Hooke had taken strides in this very direction from as early as 1668 if not the *Micrographia*:

> very many parts of the Surface of the Earth (not now to take notice of others) have been transform'd transpos'd and many ways alter'd since the first Creation of it.[325]

## 5.2 'TRANSFORM'D TRANSPOS'D AND MANY WAYS ALTER'D'

In a series of *Discourse* lectures, spanning 1688–1690, Hooke presented his defence against Plot and others' objections. Throughout these lectures, Hooke

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[323] Rappaport, *When Geologists Were Historians*, 86.

[324] Martin Lister, *An ingenious proposal for a new sort of maps of countries, together with tables of sands and clays …* in *Philosophical Transactions*, Vol. 14 (1684), 739. Rappaport, *When Geologists Were Historians*, 122. Roos, *Web of Nature,* 214–215. Cecil Schneer, 'The Rise of Historical Geology in the Seventeenth Century,' Isis, Vol. 45, No. 3 (September,1954), pp. 256–268, 262–263.

[325] Hooke, *Discourse of Earthquakes*, 317.

relies on metaphor – both as a rhetorical device and as an optical instrument that allows the imagination to peer into the insensible realm of the earth's past. Hooke is forced to rely on metaphor to move from the familiar to the obscure, and his chosen tropes and their pictorial characteristics reveal how he applies his background knowledge to spatio-temporal considerations, as well as how he approaches the study of history.

According to Hooke, the 'greatest Objection' against his hypothesis on earthquakes and subterraneous eruptions, over the course of his defence, is that it is 'thought very improbable' because 'there were wanting Instances to confirm it from History'.[326] This objection is possibly preying on Hooke's mind as the 'greatest' one because he had embarked upon extracting evidence of earthquakes and subterraneous eruptions from ancient historical sources in three linked lectures preceding this one.[327] Yet, in this respect, from 1688 to 1689, Hooke's strategy remains the same as it was in his first *Discourse* lecture of 1668:

> This Theory which I have endeavoured hitherto to evince, tho' indeed it be very hard positively to prove, we being … very deficient in Natural History, yet if we consider what has already been said, and compare it with the latest observations of divers Travailers over them, we may find it altogether more probable.[328]

Several scholars have shown that Hooke's mining of ancient historical texts, in the late 1680s, for evidence to support his hypothesis that the earth's gradually wandering poles are the cause of earthquakes and so on, was in response to the mathematician John Wallis's animadversions.[329] Important

326 Hooke, *Discourse of Earthquakes*, 404, 416.
327 Hooke, *Discourse of Earthquakes*, 371–376, 394–402, 377–384.
328 Hooke, *Discourse of Earthquakes*, 410–411. Hooke repeats in 1687 that 'our Natural History is … very thin and barren' (Hooke, *Discourse of Earthquakes*, 372). Aristotle, *Meteorology*, Book I, Part 14.
329 The underbelly of the Hooke versus Wallis debate is connected to the infamous controversy between Hooke and Hevelius concerning a difference of opinion on whether telescopic sights versus naked-eye open or plain sights are better instruments for astronomical observations. Wallis took Hevelius's side. For Hooke versus Wallis, see Oldroyd, 'Geological Controversy in the Seventeenth Century: "Hooke vs Wallis" and its Aftermath', in Hunter and Schaffer (eds), *Robert Hooke: New Studies*, 207–233. See also Turner, 'Hooke's theory of the earth's axial displacement', 166–170. For Hooke versus Hevelius, see Gal and Chen-Morris, *Baroque Science*, 101–113.

here, however, are four inter-related reversals and inversions employed by Hooke in answer to Lister and Plot's objections – the latter's in particular. First, Hooke's reversal of the claim that art is the cause of changes to the earth's surface. Second, his use of myths as natural history, like Plato's account of Atlantis in the *Timaeus,*[330] which, Hooke argues, contain parts of natural history cloaked in allegory: 'I conceive all those Mythologies have certain Historical and real Truths thereby represented'.[331] Third, Hooke's inversion of Plot's use of antiquities as objects of natural history. Finally, Hooke's explanation about why objections on the notion of extinction are not valid.

In his third *Discourse* lecture of 1688, Hooke attributes nature's stasis to art. Citing Part 14 of Aristotle's 'first Book of Meteors' liberally, Hooke argues via Aristotle that dry land swaps places with the sea over long periods of time. These periods are long 'in comparison of our short [human] Life', which is too brief to sense such gradual changes. Thus, 'the memory of [these changes] is lost'.[332] Moreover, and more important for Hooke's claim, because humans manipulate their surroundings to make them more hospitable and inhabitable, a collective memory-loss of nature's mutability occurs when nations alter the landscape so much that natural changes are stopped by art – such as dammed rivers. According to Hooke's translation of Aristotle, Egypt is a land 'made by Mud of Rivers'. But the land 'is observed to continually grow drier, and the Lakes … have been inhabited' by people. And 'length of time has obliterated the memory of such [natural] changes; for all the present Mouths of *Nile*, except the *Canobic*, have been cut by Art' in order to control the river's flow and flooding.[333] On account of these histories, which Hooke reasons

330 For Hooke's translation, see: Hooke, *Discourse of Earthquakes*, 373–374.
331 Hooke, *Discourse of Earthquakes*, 410.
332 Hooke, *Discourse of Earthquakes*, 324.
333 Hooke, *Discourse of Earthquakes*, 410–411. The E W Webster translation of the same excerpt from Aristotle, *Meteorology*, Book I, Part 14 reads as follows: 'However, all the mouths of the Nile, with the single exception of that of Canopus, are obviously artificial and not natural': Aristotle, and E W Webster (trans), *Meteorology* (Place unknown: Neeland Media, 2006 [350 BCE], Internet Classics Archive edition), unpaginated. It is interesting to note also that Pliny the Elder's encyclopaedic *Natural History* describes the Nile's delta as 'discharg[ing] itself, though by many mouths, into the Egyptian [Mediterranean] sea', though in a footnote John Bostock mentions that the 'Seven mouths in ancient times' 'dwindled' down to two: Pliny the Elder, and John Bostock (trans), *The Natural History of Pliny* (London: H G Bohn, 1855), 5.10: The River Nile.

Aristotle 'seems to be informed of by the then present *Phaenomena*, as he plainly expresses in his description of *AEgypt*', Hooke reverses Lister and Plot's claim that human hands and art, not nature, are responsible for changes to the earth's superficies. It is appropriate to mention Hannah Arendt, in *The Human Condition*, here, for she gives an interesting theoretical insight, albeit in a different context, into Hooke's need to turn the tables on the relations between civil history, natural history, stasis and motion. By dipping into Arendt's insight, we can learn a little more about this aspect of Hooke's philosophy of history. The world, Arendt argues, is 'man-made', and the durability of objects made by work, that is, "worked upon" by human hands, creates a stable natural environment.[334]

> Only we who have erected the objectivity of a world of our own from what nature gives us, who have built it into the environment of nature so that we are protected from her, can look upon nature as something "objective".[335]

In this way, Arendt claims similarly to Hooke that, contrary to Heraclitus, one *can* step into the same river twice by associating one's identity with durable artificial objects that stand against nature's changes.[336]

Hooke uses this reversal – that is, Plot's claim that art causes changes to the earth's surface – to persuade his audience that of the 'present *Phaenomena*' in Aristotle's 'description of *AEgypt*', one 'was that of the Sea-sand and [fossil] Shells'. Hooke argues that Aristotle confirms the work of the Greek historian Herodotus before him, whom Hooke had presented as a '*good Authority*' on Egypt in previous *Discourse* lectures. Herodotus, according to

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The two branches referred to by Bostock are the Rosetta and the Damietta, not the Canopic mentioned by Aristotle, which is a dead branch today: Katherine Blouin, *Triangular Landscapes: Environment, Society, and the State in the Nile Delta under Roman* Rule (Oxford: Oxford University Press, 2014), 1, 35-36.

334 Hannah Arendt, *The Human Condition* (Chicago and London: University of Chicago Press, 1958), 136. Arendt makes a clear distinction between human labour and work. Things made by labour are for consumption; whereas objects created by work are for use and have durability, such as the various dams that stop the Nile's distributaries. Thus, in labour, humans are part of nature's constant change; in work, humans stop nature's gradual changes to stabilise their environment. (I am indebted to Ofer Gal for pointing me to Arendt's work.)

335 Arendt, *The Human Condition*, 137.

336 Arendt, *The Human Condition*, 137.

Hooke, 'had taken notice of' fossils in Egypt too:[337]

> we have the Testimony of *Heroditus* in his … second Book, and twelveth Section, where speaking of the Country of *AEgypt,* as having been mostly raised by the Mud and Sand of the *Nile,* he says, the whole Country was of such a Soil, only the Mountain above *Memphis* was Sandy, and had *Conchilia* or Fishes Shells upon it …[338]

Hooke concedes that Egypt 'having been mostly raised by the Mud and Sand of the Nile' fails to explain the height of the seabed-mountain above Memphis. He concludes that either it was raised by a 'Subterraneous Power' or that 'the Sea' had at some point in the past risen 'so high as to cover that Mountain'.[339] Nevertheless, according to Hooke, the 'Testimony and Opinion of *Herodotus*' corroborates an account given by '*Pythagoras*, as related by *Ovid* in his fifteenth Book of the *Metamorphosis*, ver. 262', which reads (in 'Shakespeare's Ovid,' one of the two translations available to Hooke):

> For I have seene it sea which was substanciall ground alate,
>
> Ageine where sea was, I have seene the same become dry lond,
>
> And shelles and scales of Seafish farre have lyen from any strond,
>
> And in the toppes of mountaynes hygh old Anchors have beene found.[340]

Just as replacing the sense of sight with a microscope reveals insensible characteristic pores and marks in petrified wood, which enable Hooke to

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337 Hooke, *Discourse of Earthquakes*, 407, 411.

338 Hooke, *Discourse of Earthquakes*, 407. See also Herodotus, and A D Godley (ed and trans), *The Histories* (Cambridge: Harvard University Press, 1920), Book 2, Parts 11 and 12, available at the Perseus Project: https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0126%3Abook%3D2&force=y. Accessed in 2018. According to Herodotus, Egypt was once a gulf that the Nile silted up over deep time, leaving only one area of the original seabed exposed – the mountain over Memphis.

339 Hooke, *Discourse of Earthquakes*, 407.

340 Ovid, and Arthur Golding (trans), *Metamorphoses,* Book XV, ver. 262. Hooke's citation reads: 'Vidi ego quod fuerat quondam Solidissima tellus, esse fretum. Vidi factas ex aequore terras: Et procul a pelago conchae Jacuere Marinae. Et vetus inventa est in montibus anchora summis' (Hooke, *Discourse of Earthquakes*, 408). For the various editions of *Metamorphoses* in Hooke's library, see the excellent Hooke's Book database project: Felicity Henderson, Yelda Nasifoglue and Will Poole (eds), 'Hooke's Books Database | Robert Hooke's Books', at http://www.hookesbooks.com/hookes-books-database/.

identify it as part of a once-living fir, he claims that 'tho' rapped up in Mythology and Mascarade', Ovid's work contains 'true Histories, which now pass Incognito' that a close reading of the text can reveal. 'I did observe that *Ovid* has in some part or other of his Fable, given Marks or Characteristicks by which it may be found what the History is which he doth there Mythologize'.[341]

Hooke's use of myth is a measured, methodical discussion about history and memory, and he establishes criteria which he uses to form relations between myth and civil history parallel to the relations between fossils and natural history. He reminds his audience that it was 'a Custom of the Greeks', not to mention 'divers other Nations as the *English* and *Germans*', to turn 'Histories into Mythologick Poetry', because fables are 'better' for 'fixing' histories into, for example, 'the Minds of the Youth by a kind of indelible Character … for extravagant Marks we know are great helps of Artificial Memory, for that they raise extraordinary Attention'.[342] Namely, myth is a memory device that "marks" and "fixes" 'Artificial Memor[ies]' of historical events on the mind – as though the histories were experienced first-hand. Hooke teaches that Ovid either 'very often' writes these marks and characteristics into his transitions ('that part which serves as a Link to join the Story into a continued Chain'), or in the meanings of characters' names ('in the Etymology of Names'). He formulates rules like these for the analysis and interpretation of Ovid's compositional style, and repeats what he noted in a lecture preceding his series of answers to critics: that ''tis usual with [Ovid] all along to have and mix a treble Design', couching 'all his Relations and Expressions as to comprize a Physical, a Moral, and an Historical Meaning in

341 Hooke, *Discourse of Earthquakes*, 406.

342 Hooke, *Discourse of Earthquakes*, 396–397. Kirsten Birkett and David Oldroyd claimed that Hooke's use of ancient texts 'to verify empirically a modern scientific hypothesis' was a new mode of analysis that they call 'physico-mythology', where myths are investigated using the techniques of the new science: Kirsten Bickett and David Oldroyd, 'Robert Hooke, Physico-Mythology, Knowledge of the World of the Ancients and Knowledge of the Ancient World', in Stephen Gaukroger (ed), *The Uses of Antiquity: the Scientific Revolution and the Classical Tradition* (Dordrecht, The Netherlands: Kluwer, 1991), 145–171, 145, 154–155. Later, Oldroyd stated 'I think it plausible that some parts of myths do give a clouded record of physical events that actually happened', in David R Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (London: Athlone, 1996), 10.

them'.[343]

For example, using 'the Etymology of Names' as an analytical tool, Hooke interprets '*Perseus*'

> to signifie hot inflamed Air or Lightning which is the Earthy Exhalations set on fire by the Air dissolving them; he is said to be the Son of *Jove,* that is of Aetherial or Elementary Fire begotten in a shower of Gold or Fire from Heaven, that is Lightning.[344]

Combining his interpretations of '*Perseus, Atlas, Andromeda* and *Medusa*', Hooke hypothesises that these fables 'were designed to convey a certain History' with 'relation to the *Herculean Columns*, and to the *Atlantis*, or those parts of *Libya* which were near it'.[345]

Stretching his 'Marks or Characteristicks' metaphor to further illustrate his point, Hooke forms an analogical relation between insensible physical objects and insensible or remote history by arguing that 'much greater conclusions have been deduced from less evident and more inconsiderable Marks, if we respect Bulk, Magnitude, or Number'. That is, just as the evidence gained from studies of microscopic objects is not and should not be rejected, historical "testimonies"

> are not to be rejected for their [miniscule] bulk, tho' it be so small as no Eye or Sense can reach it unless assisted by Engines, as the Sight by a Microscope, Telescope, and the like: In how few Letters, Words, or Characters is the History of the World before *Noah's* Flood?[346]

Hooke's optical-instrumental metaphor reveals his philosophy of history. The works of ancient historians, philosophers, poets and so on provide a means to peer into the remote and obscure realm of the earth's past, and to return with the information gained there to the human-sized realm of the present, the better to understand the current state of the earth's superficies. If one subscribes to Hooke's hypothesis on fossils, then this process also works in

[343] Hooke, *Discourse of Earthquakes*, 406, 396.
[344] Hooke, *Discourse of Earthquakes*, 397.
[345] Hooke, *Discourse of Earthquakes*, 397–402.
[346] Hooke, *Discourse of Earthquakes*, 412.

reverse; that is, one can study fossils to learn about the earth's past as it is reflected in poetry and myth. Thus, based on the common thread of micro-histories on earthquakes, eruptions and "shells" on mountaintops, from Pythagoras to Herodotus to Aristotle, Hooke claims ''tis plain that this Phaenomenon of Shells was taken notice of by the Ancient Historians and Philosophers', and he turns 'every record' of changes to the earth's superficies into evidence for his causal hypothesis.[347]

### 5.3 'A TRUE HISTORY'

Hooke's love affair with Lower Egypt becomes a running theme throughout his defence as he weaves together related 'Testimonies' from civil histories and parts of myths as natural history. If he can 'prove' that ancient historical accounts of the earth's changes are "matters of fact", and if he can show that fossils 'are, or have been found in most Parts of the World',

> then it will necessarily follow that there must have been some time or other such Catastrophes, Metamorphoses, or mutations, as must have caused these parts, which were at the bottom of the Sea, to be now, or at the Time, when they were so observed, to be dry Land.[348]

In using a mixture of myth and ancient history as testimony to 'Metamorphoses' and translocations, Hooke faces two challenges. The first is a problem of chronology and time, owing to alternative timescales in ancient texts which contradict biblical chronology. The second problem, which Hooke struggles to surmount, is to convince his critics that his chosen sources are not fables, but reliable, true histories. For example, in Plato's *Timaeus*, Critias recounts a story, which his grandfather heard from the Athenian statesman Solon, about the sinking of Atlantis beyond the 'pillars of Herakles' by 'exceeding great earthquakes and floods'.[349] Hooke argues, from 1668 onwards, that there is 'Probability in the Story related by *Plato* … of the Island *Atlantis* in the *Atlantick* Ocean, which he says was swallow'd up by an

[347] Hooke, *Discourse of Earthquakes*, 406, 408. Gal, 'Nature's Grammar', 504.
[348] Hooke, *Discourse of Earthquakes*, 409, 407.
[349] Plato, and Archer Hind (ed and trans), *Timaeus* (London: Macmillan, 1888), 67.

Earthquake into the Sea'.[350] Solon heard the story from an Egyptian priest who explained that the Athenians have no memory of Atlantis sinking, because most historical records are destroyed by fire, or water, and surviving histories have 'the fashion of a fable': they have become myths. Hence the Athenians 'only remember but one deluge, whereas there had been many before it'.[351] Recall that Hooke had echoed the Egyptian priest when proclaiming the turning of 'Histories into Mythologick Poetry', a 'Custom of the *Greeks* in those former Ages'.[352] Despite this, he admits, twenty years after his first mention of Atlantis, in a lecture dated 15th of February 1688, that 'nine thousand Years is Argument enough to make the whole History to be suspected as a Fiction'.[353]

The worry for Hooke in 1688 – whether genuine or because of the shifting political-theological mood in England – is that according to the timescale given by the Egyptian priest, the founding of Athens occurred 'nine thousand years ago': three thousand years before *Genesis*, contradicting the age of the earth in the Bible. But Hooke also employs a common trick to reason with his critics that 'till we are certain what space of Time is there signified by a Year', we should not reject 'the *History* of *Plato* as brought out of *AEgypt* by *Solon*'.[354] And he complains that although

> related by *Plato,* with all the Circumstances, as if he believed it a true History, [the story of Atlantis] was yet supposed to be only a Fiction of *Plato* [by most fellows of the Royal Society] … or at best a Fable of the *AEgyptian* priest to magnify the knowledge of the *AEgyptians* as to the History of preceding Ages.[355]

Hooke's modulating tone hints at the anxieties leading to the Glorious Revolution that would occur nine months later when William of Orange, with

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350 Hooke, *Discourse of Earthquakes*, 308. For Hooke's version of the story of Atlantis, as told in Plato's *Timaeus*, see Hooke, *Discourse of Earthquakes*, 372–374.
351 Plato, *Timaeus*, 67, 75.
352 Hooke, *Discourse of Earthquakes*, 396.
353 Hooke, *Discourse of Earthquakes*, 404
354 Hooke, *Discourse of Earthquakes*, 404. According to Poole, Edmund Halley performed this trick first in his lecture on salinity, in which Halley argues that the scriptures do not reveal the duration of a day before the creation of man: Poole, *The World Makers*, 109.
355 Hooke, *Discourse of Earthquakes*, 404.

an armada powered by Protestant winds,[356] invaded England and deposed King James II.[357] It is worth mentioning that Hooke would take up journaling again just days before the Dutch invasion, possibly as an outlet for the uncertainties and growing tensions caused by shifts in the climate. For example, in his first entry dated 'Th. 1', Hooke writes: 'Query of lodging 4000 [at Gresham College]', which Gunther questions in a footnote as '? Soldiers in view of political troubles brewing'.[358] On the 5th of November, the day of William's landing at Torbay, Hooke reports: 'Dutch seen off the Isle of Wight … Dutch sayd to be landed at Pool', and then on 'W. 7', 'Dutch sayd to be landed at Tor Bay'.[359] In an entry dated 7th of December, Hooke's anxiety is palpable when, in between 'HH tea' and buying a 'black Coat', he notes 'a sham letter about massacre, increase fears. Nothing certain: all doubted'.[360] The absence of *Discourse* lectures roughly between July 1688 and May 1689 seems also to be a telling detail that Hooke was treading on dangerous ground, that there was perhaps a new need for a more conservative attitude at the time.

Back in his very next *Discourse* lecture on 22nd February 1688, Hooke forms a compromise between Plato's history and biblical chronology. He interprets the Egyptian priest's 'one deluge' that the Athenians *do* remember, 'the greatest destruction by waters', as Noah's flood, and then contradicts himself by concluding that 'the *AEgyptians* threw the History of the Flood so far backwards,' falsifying their historical records 'to make the World believe they were preceding to all others in Antiquity of History and Chronology'.[361] This move, that is, fitting the Egyptian 'History of the Flood' into the Mosaic

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[356] Jonathan I Israel and Geoffrey Parker, 'Of Providence and Protestant Winds: the Spanish Armada of 1588 and the Dutch armada of 1688', in, Jonathan I Israel (ed), *The Anglo-Dutch Moment: Essays on the Glorious Revolution and its world* impact (Cambridge: Cambridge University Press, 1991), 335–362.

[357] For an interesting account of interesting times, which follows Samuel Pepys's role as the Chief Secretary to the Admiralty before, during, and after the Dutch invasion, see Richard Ollard, *Pepys: A Biography* (Oxford: Oxford University Press, 1984), 295, 296–310. Also see Israel and Parker, 'Of Providence and Protestant Winds: the Spanish Armada of 1588 and the Dutch armada of 1688', in Israel (ed.), *The Anglo-Dutch Moment*, 335–362.

[358] Robert Hooke, *Diary*, *1688 to 1693*, in Robert Theodore Gunther (ed,) *Early Science in Oxford*, Vol. X (Oxford, Printed for the Author, 1935), 69.

[359] Hooke, *Diary*, *1688 to 1693*, in Gunther (ed), *Early Science in Oxford*, Vol. X, 70–71.

[360] Hooke, *Diary*, *1688 to 1693*, 80.

[361] Hooke, *Discourse of Earthquakes*, 408. Plato, *Timaeus*, 75.

framework, is possibly a result of Hooke having to keep his fluid biblical approach contained during the straining political-theological tensions sketched above. It constructs an assemblage of natural history from fragments of his imaginings and interpretations of ancient histories and myths, as well as exegesis of *Genesis*. The assemblage depicts both Hooke's suddenly distracted and guarded mode of perception when it comes to the placement of natural disasters in the earth's past on a timeline, and his need to authenticate his fragments of natural history by situating them within a biblical chronology.[362] It is a relation between Hooke and his texts that is better explained by borrowing his remarks about the historicity of events in sources such as Ovid's *Metamorphoses*: just as Hooke's attempt to construct a natural history from parts is a relation between him and his texts, 'the Metamorphosis of *Ovid*' is a relation between Ovid as a 'Modern' 'with respect to' the ancients who came before him.[363] And just as Ovid erects a structure 'up of such Fragments or Parts', which has a 'new Disposition and Order', although his 'Conjectures might not be all right, yet we cannot but think they might be tolerably near the matter'.[364] However, Hooke's compromise – squeezing ancient historical timescales into the biblical one – has the effect of epistemologically weakening his argument, because he himself apparently no longer trusts the given Egyptian chronology in Plato's *Timaeus*, so why should objectors to his historiography.

Nonetheless, Hooke attempts to develop and strengthen his supportive argument by increasing his number of 'Witnesses'. That is, by referencing several other ancient sources who, according to his interpretation, also believe Plato's account of Atlantis to be a 'true History'.[365] In a late 1687 *Discourse* lecture, Hooke promises to provide, at some future date, a 'Cloud of Witnesses'

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[362] For an alternative interpretation, which suggests that Hooke's sudden need to comply with the Mosaic narrative was a modification resulting solely from his correspondence with Wallis, see Oldroyd, 'Geological Controversy in the Seventeenth Century: "Hooke vs Wallis" and its Aftermath', in Hunter and Schaffer (eds), *Robert Hooke: New Studies*, 207, 229.
[363] Hooke, *Discourse of Earthquakes*, 394.
[364] Hooke, *Discourse of Earthquakes*, 394.
[365] Hooke, *Discourse of Earthquakes*, 406.

to testify that 'the *Periplus* of *Hanno* the *Carthaginian*' describes 'the remainders of the Island of Atlantis, and it seems to be of a later date much than the *Egyptian* Stories'.[366] That it *is* of a much later date is important 'because the Scene of this Tragedy of *Atlantis* was placed very far backwards in times remote', so the *Periplus* is Hooke's

> indeavour to produce some History concerning the [natural] changes that happened since that time, namely, within the reach of Greek Histories, in the same place where this *Atlantis* was said to be sunk down into the Sea.[367]

He explains that the *Periplus* is a credible source because 'the *Phaencians*, of whom the *Carthaginians* were a Colony, were so early eminent in Arts, especially in that of Navigation and Traffick;' even '*Solon* made use of them'.[368] If the *Periplus* accurately documents the voyage, then, Hooke argues, this further corroborates his claim that the earth's surface is still changing, because the remains of Atlantis 'are not now to be found in the places where they are by that Relation placed'. Thus 'there must needs have happened great changes in those Parts between the time of this Expedition and the present'. Again, the acceptance of such changes is crucial for Hooke because it is 'necessary to make out the Hypothesis of the figured Bodies, which are found to be real Shells … and to have been by them disposed and situated in the places where they are now found'.[369] But since 'this Relation [between Solon's story in Plato's *Timaeus* and Hanno's *Periplus*] was also looked upon as fabulous' by Hooke's detractors, he was forced to deliver his promised 'Cloud of Witnesses' in early 1688, by constructing a genealogical tree from Hanno to Aristotle.

The tree is designed to persuade Hooke's audience that although 'we have but very little of the History of the Times, yet by those few Fragments dispersed here and there, we may be sufficiently satisfied' that Hanno could

366 Hooke, *Discourse of Earthquakes*, 375. For Hooke's translation of the *Periplus*, see Hooke, *Discourse of Earthquakes*, 375–376.
367 Hooke, *Discourse of Earthquakes*, 404–405.
368 Hooke, *Discourse of Earthquakes*, 406.
369 Hooke, *Discourse of Earthquakes*, 405.

and did make the voyage documented by his periplus. Hooke draws lines of descent from the Phoenicians, 'of whom the Carthagians were a Colony', to the Greeks, for

> Thales was a *Phaenician*, and *Pherecides* who was the Master of *Pythagoras*, and the founder of the Italick [Pythagorean] Phylosophy … And from *Pythagoras* his Philosophy sprang and flowed both the *Platonick* Philosophy, and also the Philosophy of his Scholar *Aristotle* ...[370]

Via this tree of knowledge, ethnicity and civilisation, Hooke attempts to develop a history to show that since 'the Philosophy of the Greeks was derived principally from' the Phoenicians, including 'also Astronomy', which is paramount for navigation, the *Periplus* of Hanno is a reliable source of knowledge. Since Hooke and his peers inherited pieces of Greek science, the implicit premise is that to discount the *Periplus* as 'fabulous' is to discount the natural philosophy that came after it as fabulous, too. It may seem like an outlandish move, at odds with Hooke's previous remarks on and use of fragments, but this is *not* one of his natural histories. Therefore, Hooke has no need for the 'Cloud of Witnesses' to represent change. Rather, it is a sweeping cloud of *civil* history, and its overarching claim about the transfer of Phoenician knowledge approximates, whether intentional or not, the stasis imposed on nature by art. Adding more witnesses and testimonies as scaffolding, Hooke also argues from Strabo's descriptions of earthquakes in the 'second book' of his *Geographica* that 'both *Strabo* and *Eratosthenes* did look upon the History of *Plato,* or rather the *AEgyptians*, as very probable'.[371] By 'second book', Hooke means Strabo's remark that Poseidonius 'correctly sets down in his work the fact that the earth sometimes rises and undergoes settling processes',[372]

> and undergoes changes that result from earthquakes and other similar agencies, *all of which I too have enumerated above.* And on this point he

[370] Hooke, *Discourse of Earthquakes*, 406.
[371] Hooke, *Discourse of Earthquakes*, 404.
[372] Strabo, and Horace Leonard Jones (ed and trans), *Geography, Books 1-17 in 8 Volumes* (London: William Heinemann | New York: G P Putnam's Sons | Loeb Classical Library edition, 1917), 391 [2. 3. 5–6]. (Henceforth *Geographica*.)

> does well to cite the statement of Plato that it is possible that the story about the island of Atlantis is not a fiction.[373]

But with the words 'all of which I have enumerated above', Strabo is referencing the first book of his *Geographica,* not the second, as cited by Hooke. This is possibly an error on Hooke's part.

Moreover, that Hooke neglects to mention Poseidonius may indicate that he prefers the authority of Eratosthenes, whom Strabo both praises and criticises,[374] and so chooses to use him and Strabo together for rhetorical purposes. Why Hooke may prefer Eratosthenes on earthquakes in Strabo's account remains unclear; first, because Strabo cites a plethora of sources on earthquakes and volcanic eruptions; and second, because Strabo consistently refutes Eratosthenes's claim that poetry like Homer's is for entertainment rather than instruction, even if it contains mythical elements, which is the thesis that Hooke also attempts to defend.[375] Hooke also reckons that Pliny's *Natural History*[376] documents earthquakes and eruptions that occurred 'in the same place where this Atlantis was said to be sunk down into the Sea', further supporting his argument that there were 'Islands both greater and smaller to the Westwards of the Streights [of Gibraltar] Mouth, which are now not to be found, and consequently they must have suffered a Submersion by some intervening Catastrophes'. Finally, employing the same strategy as in his first *Discourse* lecture of 1668, Hooke strives to convince his critics that *current* events in the same region validate his tapestry of ancient historical records on Atlantis. For example, 'the alterations by Eruptions out of the Sea near the Islands of the *Canarys*' in the Atlantic (the Canary archipelago is approximately 1,300 km from the Strait of Gibraltar).[377] But most of Hooke's naysayers, especially the *lapides sui generis* supporters such as Lister and Plot, would remain obstinately unconvinced, claiming that his 'Histories' were works

[373] Strabo, *Geographica*, 391 [2. 3. 5–6]. Italics added.
[374] See, for example, Strabo, *Geographica*, 179 [1. 3. 2–3].
[375] See, for example, Strabo, *Geographica*, 23 [1. 1. 10–12].
[376] See especially Pliny, *Natural History*, Book VI. For instance, in the first paragraph of Chapter XXXI, Pliny mentions 'another Island before the Mountain Atlas, and which is named Atlantis'.
[377] Hooke, *Discourse of Earthquakes*, 406.

of 'Fiction and Romantick', meaning that his histories were not data available to the senses.[378]

### 5.4 'Records of Antiquity'

Although Hooke remarks that the 'greatest Objection' against his hypothesis on fossils is that 'there were wanting Instances to confirm it from History', there were also serious ontological objections. We discussed Plot's definition of what a fossil is previously. For Hooke, to define fossils as formed or figured stones is to multiply entities without necessity. Wielding Ockham's razor, Hooke rips into the ad hoc *lusus naturae* explanation favoured by the *lapides sui generis* supporters.

> I need to repeat what I have formerly said as to the several curiously figured Stones found in … all parts of the Earth, that they are really the several Bodies they represent, or the mouldings of them Petrified, and not, as some have imagined, a *Lusus Naturae* sporting her self in the need less formation of useless Beings.[379]

Treating fossils as mimetic objects sculpted from stone diminishes their usefulness as objects of historical knowledge by turning them into curios. In contrast, by defining fossils as re-*presentations* of once living beings, their epistemological significance for Hooke as a 'Natural Antiquary' is that they can 'so well inform' that 'such and such places have been under the Water, that there have been such kind of Animals, that there have been such preceding Alterations and changes of the superficial Parts of the Earth'. That is, their significance is as 'Monuments and Records to instruct succeeding Ages of what past in preceding'.[380] Rossi suggests that the *lapides sui generis*

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[378] Hooke, *Discourse of Earthquakes*, 404–405, 407. Thomas Burnet, in preface to his *The Sacred Theory of the Earth*, explains the use of 'fiction and romantic' in this context when he states that 'men of short Thoughts and little Meditation … are apt to distrust every Thing for a Fancy or Fiction that is not the Dictate of Sense, or made out immediately to the Senses. Men of this Humour and Character call such Theories as these Philosophick Romances, and think themselves witty in the Expression': Thomas Burnet, *Sacred Theory of the Earth* … Vol. 1–2 (London: Printed by R.N. for Walter Kettilby …, 1697), xxi–xxii.

[379] Hooke, *Discourse of Earthquakes*, 403.

[380] Hooke, *Discourse of Earthquakes*, 321. For an erudite analysis of Hooke's use of this metaphor, see Gal, 'Nature's Grammar'.

hypothesis, namely an image of fossils 'as a series of immutable forms and as an ordering of permanent structures', resulted from naturalists' aims to describe and classify nature instead of studying its 'alterations and transformations'.[381] Further, he argues that Hooke and others' interpretation of fossils 'as a set of structures that were only apparently constant' allowed for 'an image of nature as a process that takes place in time'.[382] This complements the Baroque theme of motion-as-process – of events and things captured in the middle of the action. As shown, Hooke examines two physical processes that alter the earth's surface through time: occasional catastrophes, which destroy historical records, and gradual changes, which are stopped by art.

In a slightly earlier justification of his 'Doctrine' on the figure of the earth and its alterations, Hooke reminds everyone that 'extravagant' suppositions such as his 'have not only been made, but accepted and imbraced, and for many Ages as stifly defended as the most probable'. He has 'the *Ptolemaick* Hypothesis of the Heavens' in mind,

> the reason of which proceeded from one false Principle, that one Body was capable of no more than one simple motion, whereas in truth there is no body mov'd but is … actually mov'd by thousands.[383]

If Earth is 'mov'd by thousands' of motions, Hooke expects that it should also have thousands of internal motions, reflected by a dynamic superficies. Again, Hooke enforces order upon nature with motion, not stasis, and he recycles this conjecture when forced to explain why objections to extinction are not valid. Hence, in Hooke's new practice of observation, seemingly static fossils, by the very processes of petrifaction, are paradoxically a synecdoche of nature's variety and change. Marine fossils, found in places where they ought not to be, represent these alterations as re-presentations that persist, through deep time and historical material and spatial changes, in retaining the identity of extinct things. Without them, there would be few traces either of processes like transformation, metamorphosis, and translocation, or of things that had existed

381 Rossi, *The Dark Abyss of Time*, 4, 13.
382 Rossi, *The Dark Abyss of Time*, 4, 108–109.
383 Hooke, *Discourse of Earthquakes,* 350.

and natural events that had happened once upon a time. 'And tho' it must be granted, that it is very difficult to read them, and to raise a *Chronology* out of them, and to state the intervalls of the Times wherein such, or such Catastrophes and Mutations have happened; yet 'tis not impossible'.[384]

In the last two lectures of his four-lecture series of answers to objections, Hooke confronts Plot implicitly on three fronts. First, Plot's use of artificial objects as objects of nature. Second, with a defence of extinction. Third, which I examine in Chapter 6, Hooke rejects Plot's crystallisation hypothesis as a causal mechanism for the formation of *all* fossils. Hooke's answers are tailored to Plot more so than anybody else because they correspond to Plot's objections in *Oxford-shire* and *Stafford-shire*.

Hooke begins with an inversion of Plot's use of antiquities, that is, his use of ruins of art as objects of natural history.

> Men do generally too much slight and pass over without regard these Records of Antiquity which Nature have left as Monuments … of preceding Transactions … of the Body of the Earth, which are infinitely more evident … than any thing of Antiquity that can be fetched out of Coins or Medals …[385]

Moreover, Hooke points out again that objects of art can be counterfeited. '[T]he best of those [antiquities] may be counterfeited or made by Art and Design, as may also Books, Manuscripts, and Inscriptions'.[386] For instance, the clergyman John Bargrave (1610–1680) travelled the Continent collecting curiosities – including *counterfeited* antiquities.[387] Whereas fossils cannot be counterfeited by art: 'these Characters are not to be counterfeited by all the Craft in the World,' Hooke reiterates, 'nor can they be doubted to be, what they appear, by any one that will impartially examine the true appearances of them'.[388] This is an important point about historicity, because, unlike external appearances, the internal, microscopic marks identified by Hooke are not

[384] Hooke, *Discourse of Earthquakes*, 411.
[385] Hooke, *Discourse of Earthquakes*, 411.
[386] Hooke, *Discourse of Earthquakes*, 411 (also see page 397).
[387] Marjorie Swann, *Curiosities and Texts: the Culture of Collecting in Early Modern England* (Pennsylvania, USA: University of Pennsylvania Press, 2001), 3.
[388] Hooke, *Discourse of Earthquakes*, 411 (also see page 397).

accidents, and being both microscopic and internal, these essential qualities cannot be counterfeited artificially. Thus fossils contain a rich internal repository of actual Earth history.

The separation of antiquities from natural objects and the reclamation of antiquities as a metaphor for fossils are crucial steps in Hooke's development and application of 'Characters'. Indeed, 'Characters' are a subset of the antiquities metaphor, indicating that fossils, or nature's antiquities, can be read like coins, medals, monuments and so on. This conceit (extended metaphor) is part and parcel of Hooke's coinage of 'Characteristicks' or marks, a theoretical tool defining a collection of features used for the identification of new physical objects of the new science – such as the characteristic pores in petrified wood previously discussed. Thus, at a fundamental level, nature's antiquities, characters and 'Characteristicks' serve to invert the thought-practices of Hooke's audience by encouraging them to think of fossils in terms of antiquities, and to translate these thoughts into experimental observation and practice. When concluding this part of his response, Hooke takes care to address not only Plot and others in the *lapides sui generis* cohort, but Wallis as well, who, in a 1687 letter to Edmond Halley, accused Hooke of being a radical with the claim that he had 'turned [the world] upside down' (in reference to Hooke's hypothesis on the earth's gradually wandering poles as the causal mechanism behind earthquakes and eruptions) for 'some Fish-shels'.[389] Accusing one of "turning the world upside down" was hurled as a verbal weapon at religious radicals and perceived occultists during the English civil

[389] John Wallis, *Wallis to Halley. Oxford, 4 March 1686/7*, transcribed in A J Turner, 'Hooke's Theory of the Earth's Axial Displacement: Some Contemporary Opinion' (*The British Journal for the History of Science*, Vol. 7, No. 2 (July, 1974), pp. 166-170), 167, 169. See also David R Oldroyd, 'Geological Controversy in the Seventeenth Century: "Hooke vs Wallis" and its Aftermath', in Hunter and Schaffer (eds), *Robert Hooke: New Studies* (Place unknown: Boydell Press, 1989), 212. In Robert Hooke, *Ansr to Dr Wallis & Ways to find ye Meridian. Read to ye RS Apr. 27. 1687,* when summarising Wallis's arguments against his hypothesis, Hooke seems to take the accusation literally when he writes 'why he [Wallis] should call this slow variation of the Axis of Rotation a turning the world upside down I cannot conceive … Since whoever admits the Copernican Hypothesis allowes 10000 more [turnings]': transcribed in Oldroyd, 'Geological Controversy in the Seventeenth Century: "Hooke vs Wallis" and its Aftermath', in Hunter and Schaffer (eds), *Robert Hooke: New Studies*, 213. For Hooke's hypothesis, see Hooke, *Discourse of Earthquakes*, 346.

war as well as the Restoration.[390] Yet that '*nobler* Superstructures' can be raised from 'meanest foundations' is a methodological maxim of Hooke's, and in one fell swoop, Hooke retorts:[391]

> tho' possibly some may say, I have turned the World upside down for the sake of a Shell … [yet] by means of so slight and trivial Signs and Tokens as these [fossils] are, there can be Discoveries made and certain Conclusions drawn of infinitely more important Subjects …[392]

Another one of these allegedly 'infinitely more important Subjects', which casts contrasting light on the theme of ruins and decay, is extinction.

[390] Linden, *Darke Hierogliphicks,* 34. Also see Christopher Hill, *The World Turned Upside Down: Radical Ideas during the English Revolution* (London: Temple Smith, 1972).
[391] Hooke, *Micrographia*, Preface, unpaginated.
[392] Hooke, *Discourse of Earthquakes*, 411–412.

# CHAPTER 6: 'SO UTTERLY EXTINCT AND GONE'

In his *Sacred Theory of the Earth* (the first volume first English'd from the Latin in 1684), the theologian-cosmogonist Thomas Burnet (c. 1635–1715) instructs his readers on how to make a 'discovery at a distance', as if with an optical instrument, with regular appeals to the imagination.[393] Imagine

> That the face of the Earth before the Deluge was smooth, regular and uniform; without Mountains, and without Sea.[394]

This was 'the first or Ante-diluvian Earth'. In contrast to this imagined 'primigenial Earth', mountains, caverns, jagged coastlines and other irregularities are tilted and jutting parts of a shattered superficies – the remains of something that was perfect once upon a time on a very nearly different planet (Figure 8). Describing the present state of the earth, 'the Earth as it is really in it self', Burnet makes the following observation:

> though it be handsome and regular enough to the eye in certain parts of it, single tracts and single Regions; yet if we consider the whole surface of it, or the whole Exteriour Region, 'tis as a broken and confus'd heap of bodies, plac'd in no order to one another, nor with any correspondency or regularity of parts[.][395]

Further, employing a trope first fashioned by Galileo in his *Sidereus Nuncius* (1610), a description of the maculate superficies of the moon that had become a commonplace conceptual idiom by Burnet's time, used to great

[393] Burnet, *The Sacred Theory of the Earth*, 34.
[394] Burnet, *The Sacred Theory of the Earth*, 34.
[395] Burnet, *The Sacred Theory of the Earth*, 74.

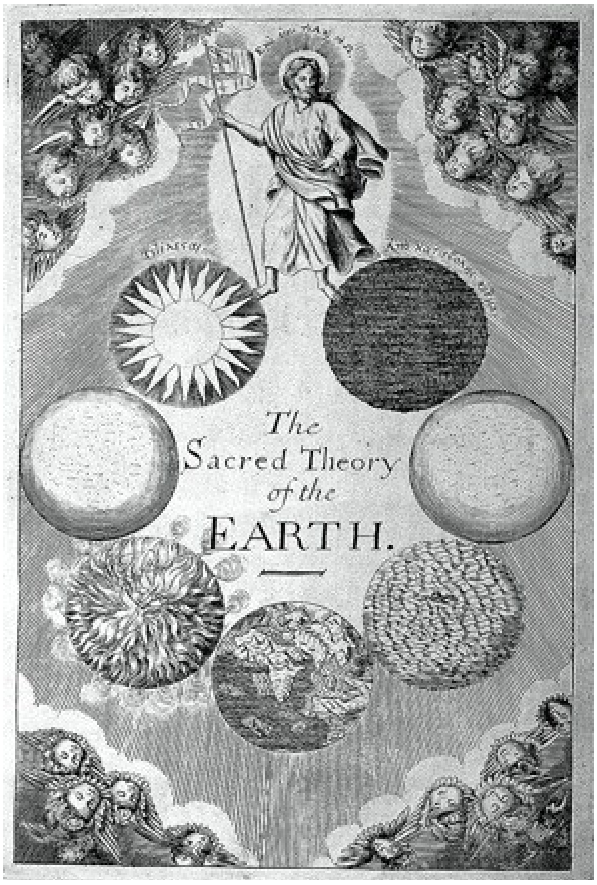


*Figure 8: The frontispiece of Burnet's* Sacred Theory of the Earth *(1697), illustrating the seven epochs of the past, present, and future history of Earth. Credit: Wellcome Collection. Attribution 4.0 International (CC BY 4.0) https://wellcomecollection.org/works/tcfggv7s*

effect in various ways by Hooke and others, Burnet makes a comparison between the earth and the moon.[396]

> And such a body as the Moon appears to us, when 'tis look'd upon with a good Glass, rude and ragged; as it is also represented in the modern Maps of the Moon; such a thing would the Earth appear if it was seen from the Moon.[397]

Imagining what the earth would look like when viewed from the moon is also nothing new. For example, Kepler journeyed to the moon in his *Somnium*, and Hooke's mentor John Wilkins made a similar flight of fancy.[398] But unlike Kepler, Wilkins and Hooke, to whom we will return at the end of Chapter 7 when examining the moon from the latter's perspective, Burnet's journey serves to solidify a conclusion that is both lovely and devastating: 'They are both [the earth and the moon] in my judgement the image or picture of a great Ruine, and have the true aspect of a World lying

[396] Hodoba Eric, *The Capture of Spring*; Galileo Galilei, and Edward Stafford Carlos (trans), *The Sidereal Messenger of Galileo Galilei and a Part of the Preface of Kepler's Dioptrics Containing the Original Account of Galileo's Astronomical Discoveries* (London: Rivingtons, 1880), 40; Reeves, *Painting the Heavens.*

[397] Burnet, *The Sacred Theory of the Earth*, 74–75.

[398] Johannes Kepler, and Edward Rosen (trans), *Somnium: the Dream, or Posthumous Work on Lunar Astronomy* (New York: Dover, 2003). John Wilkins, *The Discovery of a New World [in the Moon]*, in John Wilkins, *The Mathematical and Philosophical Works of the Right Reverend John Wilkins …* (London: J Nicholson, 1708 [1638]). See also Hodoba Eric, *The Capture of Spring*, 118, 136.

in its rubbish'.[399]

It is lovely because the 'greatest objects of Nature', such as mountains, are 'the most pleasing to behold', for one does 'naturally, upon such occassions, think of God, and his greatness'.[400] And after 'the great Concave of the Heavens, and those boundless Regions where the Stars inhabit', there is nothing that gives Burnet 'more pleasure than the wide Sea and the Mountains of the Earth', for there is 'something august and stately in the Air of these things, that inspires the mind with great thoughts and passions'.[401] It is both lovely and devastating because thinking on the greatness of mountains and God leads to a sublime moment where things are 'too big for our comprehension' and 'fill and overbear the mind with their Excess, and cast it into a pleasing kind of stupor and admiration'.[402] It is devastating because if the most majestic natural objects are beyond human comprehension, then there are limits on just how close one can approach God via nature. Moreover, because these great ruins are evidence of a catastrophe in the earth's past, they also serve as a memento mori of the coming conflagration. For example, in a pessimistic passage censored from the English translation of the *Sacred Theory*, Burnet asks, 'How is it possible to confide in a transient world, which will be reduced to cinders and smoke in the space of a century or two?'[403] Alongside what Rossi referred to as this 'metaphysical leitmotif' of ruin, the concept of the earth in decay like an organic body – what Clarence Glacken called senescence – also permeated Baroque culture.[404]

Some historians have claimed that seventeenth century notions on ruin and especially decay were mediaeval and sixteenth century commonplaces, brought about by the lingering belief that the moral and physical decay of man, after the expulsion of Adam and Eve from the Garden of Eden,

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[399] Burnet, *The Sacred Theory of the Earth*, 75.
[400] Burnet, *The Sacred Theory of the Earth*, 94–95.
[401] Burnet, *The Sacred Theory of the Earth*, 94.
[402] Burnet, The Sacred Theory of the Earth, 95.
[403] Cited by Rossi, in *The Dark Abyss of Time*, 38 (see also page 36).
[404] Rossi, *The Dark Abyss of Time*, 36; Clarence J Glacken, *Traces on the Rhodian Shore* (Berkeley and L A: University of California Press, 1967), 379.

corresponded to ruin and decay in nature.[405] However, as noted by Glacken, it became necessary to refute this view, which contradicted the principle of providence – that is, of a perfectly ordered and harmonious Earth designed by a benevolent creator, for the use of man.[406] More importantly, the way that ruin and decay were altered and deployed in opposing arguments on earth history shows that neither was a seventeenth century commonplace; nor were they tropes, because unlike Galileo's maculate moon, there was no consensus on what ruin and decay represented. Burnet is a popular example of one use of ruins. From 1668 onwards, Hooke would employ both ruin and decay to buttress his claims on fossils and extinction by arguing that the earth's superficies is constructed of layers of ruins shored up by more ruins – the result of a natural cyclical process of growth and decay. But not everyone agreed with Burnet or Hooke. As discussed in preceding chapters, John Ray attempted a fossils compromise – promoting Hooke's ideas on the origin of petrified bodies while proposing not extinction, but a lack of exploration as the reason for why fossils do not resemble any known living species. According to Ray, both Hooke and Burnet were wrong, and in dangerous ways that could stir thoughts towards atheism, thus it became necessary for Ray to represent ruin and decay as mechanisms of providence. By juxtaposing Hooke and Ray, we will examine how ruin and decay were used as tools in opposing arguments about extinction, and thus how extinction throws contrasting light on these themes.

Ray works especially hard to negate Hooke's argument that one causal factor of extinction is 'Animals and Vegetables peculiar to certain places, and not to be found elsewhere';[407] and he also reacts strongly against Burnet's *Sacred Theory* because of its portrayal of the earth as an imperfect place.[408] Ray's struggles to solve the paradox of a world operating by providence yet

[405] See, for example, Gordon L Davies, *The Earth in Decay: a history of British geomorphology, 1578–1878* (Place unknown: Macdonald Technical and Scientific, 1969), 6–7. Glacken, *Traces on the Rhodian Shore*, 379.
[406] Glacken, *Traces on the Rhodian Shore*, 379.
[407] Hooke, *Discourse of Earthquakes*, 327.
[408] According to Gordon Davies, in *The Earth in Decay,* all problems with ruin and decay result from the belief that the earth was created to be a habitable and resourceful place for man, 4–5.

simultaneously decaying, and to factor out extinction by keeping within the constraints of the Mosaic timescale while at the same time defending the organic origins hypothesis for fossils, are fascinating because he does not constrain himself to his own predominantly ocular studies as evidence for his claims, but weaves the radically instrumentalised observations of Hooke and others into his explanations. In this way, Ray subjects history to the results of Hooke's investigative procedures together with his own studies to construct visual meanings that serve contrary metaphysical commitments. Thus, in the final section of this chapter, we will analyse why and how Ray borrows objects that are products of the instrumentalisation of vision to fill gaps in his imagined account of uninterrupted generation and lineage. Together, Hooke and Ray exemplify how the same theoretical and practical tools, heavily reliant on the imagination and the re-drawing of its limits, were used to quell or enhance epistemological anxieties.

## 6.1 'RUIN'

The explorer-poet-soldier-spy Sir Walter Raleigh (circa 1552/'54–1618), during a long stretch in the Tower of London,[409] and pondering the problem of the Flood, jotted in his *History of the World* "That there was no need of any new Creation of matter to make the universal Flood'. Moreover,

> if it be objected, that God doth not create any thing of new; (for God resteth the seventh day; (that is) he did not then after create any new *species*) … Of this Proposition, Whether God hath so restrained himself or no, I will not dispute.[410]

This refusal to 'dispute' matters that could lead to speculations on the perfection of the original Creation, or contradict the doctrines of Providence and plenitude, as shown with Lister and Plot earlier, both of whom refused to assume any notion that implied either of these things, was the general public

[409] Patrick Fraser Tytler, *Life of Sir Walter Raleigh: founded on authentic and original documents* (London: T Nelson and Sons, Paternoster Row, 1853), 20.

[410] Walter Raleigh [spelt 'Ralegh' in this edition], *The History of the World, in Five Books*, (London: Printed for *Tho. Basset*, et al., 1687), The First Book of the First Part, Chapter VII, 60.

attitude during and after Hooke's time. As mentioned, Hooke found himself very alone with his radical and scandalous ideas on extinction (and earthquakes and eruptions as the causal mechanisms), upsetting even those naturalists and natural philosophers who were otherwise supportive of his lectures on fossils, such as Ray, to whom we will return momentarily.

To recapitulate, on the one hand, Plot observes and describes the relics and ruins of extinct civilisations *as* natural history, enforcing antiquities upon nature to explain away estranging spatio-temporal changes, because for him natural alterations to the earth's surface would signify movement away from the order and perfection of Creation. On the other, Hooke studies the natural fragments *caused by* the earth's tottering shifts and slips, such as broken and flattened marine fossils and sandy mountaintops, and he argues that these fragments and ruins are traces of nature's dynamic harmony not its imperfection. Hooke projects decaying and petrified shells, and ruins of human history and memory of nature's changes, onto nature by addressing specifically the accusation made against him concerning extinction: that 'to suppose such a Doctrine as doth necessarily infer such a Consequence, is … absurd and extravagant; for that it would argue an imperfection of the first Creation'.[411] And he attempts to turn it on its head by enforcing order upon the earth's sometimes catastrophic and always gradually shifting motions. This move, Hooke declares, does not in any way 'contradict any part of the Scripture, or any Conclusion of the most eminent Philosophers, or any rational Argument that may be drawn from the Phaenomena of nature'; rather, '*quite contrary Inferences* … must, and ought, to be made'.[412] For

> we find nothing in Holy Writ that seems to argue such a constancy of Nature; but on the contrary, many Expressions that denote a continual decay, and a tendency to a final Dissolution …[413]

To support these statements, Hooke begins by borrowing Ray's compromise –

[411] Hooke, *Discourse of Earthquakes*, 433.
[412] Hooke, *Discourse of Earthquakes*, 435. Italics added.
[413] Hooke, *Discourse of Earthquakes*, 435.

discussed earlier when examining the postscripts to Lister's rock-plants – using a large '*Ophiomorphite'* (ammonite) to illustrate his point. Although 'at present no such *Nautili*' have been found 'upon the Coast or Shores of the Lands where' these kinds of ammonites are found, 'no one is assured that there are not some of the same Species, as big in some other parts of the World, as possibly at the bottoms of some of the great Oceans.' Especially, Hooke indicates, because of the tremendous 'variety of testaceous and crustaceous Animals' 'found in soundable Depths'. Here, Ray's compromise serves as a gentle introduction to Hooke's 'Doctrine', which Hooke *insists* 'we will, for the present, take … to be real and true'.[414]

The supposition 'that there have been in former times of the World, divers *Species* of Creatures, that are now quite lost, and no more of them surviving upon any part of the Earth'.[415]

> We will further grant there may have been, by mixture of Creatures, produced a sort of differing in Shape, both from the Created Forms of the one and other Compounders, and from the true Created Shapes of both of them.[416]

What Hooke means by this is a 'mixture' or compounding within a species. He first mentions this conjecture about 'Compounders' in the *Micrographia's* 'Observ. L. *Of the wandring* Mite', from observations initially made through his window, in 1661 and 1663, in Oxford and London respectively.[417] According to him, alterations to animate bodies can occur in two ways: acclimatisation to a new environment, or by harmonious animate bodies compounding. Examining two mites under a microscope, Hooke speculates from the anatomy of one that he has 'found out the vagabond Parents of those Mites we find in

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414 Hooke, *Discourse of Earthquakes*, 433–434. The following year, in late 1691, Hooke made some more improvements on sounding instruments, which he worked on, on and off, from as early as 1663: Robert Hooke, *Instruments for Sounding the Great Depths of the Sea*, in Robert Hooke et al., *Philosophical Experiments and Observations*… (London: W. Derham, F.R.S., 1726), 225–235. Meghan C Doherty, Chapter 4: *'Ordinary Skill in Cutts': Visual Translation in Early Modern Learned Journals*, in Sietske Fransen, Niall Hodson and Karl A E Enenkel (eds), *Translating Early Modern Science* (Leiden, The Netherlands: Brill, 2017), 91–116.

415 Hooke, *Discourse of Earthquakes*, 435.

416 Hooke, *Discourse of Earthquakes,* 435.

417 Hooke, *Micrographia*, 205–207.

… musty Barrels, Musty Leather' and so on. He imagines that these mites, by travelling around in search of 'pleasing territories', encounter new environments and gradually undergo physical alterations. For example, by 'the change of the soil and Country they now inhabite,' the mites 'might be quite alter'd from … their *primogenitors*, and, like *Mores* translated into Northern *European* Climates, after a little time, change both their skin and shape.'[418] Or, as '[w]e find by relations how much the *Negro* Women do besmear the of-spring of the *Spaniard*, bringing forth neither white-skinn'd nor black, but tawny hided *Mulattos*', mites in 'Musty Leather' may be the result of a similar compounding.[419] This gives Hooke reason enough to conjecture that 'the causes of those creatures whose original seems yet so obscure … may be innobled with a Pedigree as ancient as the first creation'. *But*, he is quick to add that 'on the other side, if it should be found that these or any other animate body, have no immediate similar Parent,' then

> I have in another place set down a conjectural *Hypothesis* whereby those *Phaenomena* may likely enough be solv'd, whereby the infinite wisdom and providence of the Creator is no less rare and wonderful.[420]

Indeed, in a 1664 Royal Society meeting, Hooke presented another paper on petrifactions, which was also to be part of the *Micrographia*. Yet his employers were so scandalised by his idea on 'the ends of such petrifactions' that they immediately decreed its redaction:

> There was a paper of Mr. HOOKE'S concerning petrifactions, designed by him as part of his microscopical book, then in the press. The Society approved of the modesty used in his assertions, but advised him to omit what he had delivered concerning the ends of such petrifactions.[421]

It is, of course, the very same conjecture that Hooke strives to develop 'in another place' throughout his *Discourse* lectures. For example, in 1668, Hooke

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[418] Hooke, *Micrographia*, 206.
[419] Hooke, *Micrographia*, 207.
[420] Hooke, *Micrographia*, 207.
[421] Birch, *The History of the Royal Society of London*, Vol. 1, 463. See also the Hooke Folio: CELL/RS/HF_010 © Centre for Editing Lives and Letters.

argues that

> there may have been divers Species of things wholly destroyed and annihilated, and divers others changed and varied … since we find that there are some kinds of Animals and Vegetables peculiar to certain places, and not to be found elsewhere.[422]

Destruction of place annihilates the fauna and flora peculiar to that place. But a milder 'alteration of the Climate' causes subtler changes 'in those Bodies that suffer it', visible as variation of shape. Note that sudden destruction versus change of climate corresponds to the two physical processes which Hooke attributes to alterations of the earth's surface through time: occasional catastrophes, which destroy historical records as well as civilisations, and dynamic gradual changes, which are stopped by art. Because of destruction and change of climate, there 'may have been divers new varieties generated of the same Species'. Whence Hooke concludes, 'I imagine [this] to be the reason of the great variety of Creatures that do properly belong to one Species'.[423]

Further, 'we will grant also a supposition that several *Species* … have changed in great part their Shape, as well as dwindled and degenerated into a dwarfish Progeny'. Indeed, they have transformed so much that one would be hard pressed to judge them 'of the same Species'. It is obvious, from his citation of Aristotle's *Meteorology* a couple of lectures earlier, that Hooke is appropriating the concept on how sea and dry land are 'changed in time', 'from interior changes of the Earth, which from a long Constitution grows old [and decays], as the Bodies of Plants and Animals, and that not singly the Parts but the whole'.[424] Comparing 'the Earth' with 'the Bodies of Plants and Animals' in this manner is neither new nor novel. But by taking Aristotle's simile literally, and applying this concept on the body of the earth to the petrifying body of a fossil, be it of rotting 'plant' or 'animal' origin, Hooke again uses the fossil as a synecdoche of the earth's changes in time.

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422 Hooke, *Discourse of Earthquakes*, 327.
423 Hooke, *Discourse of Earthquakes*, 327–328.
424 Hooke, *Discourse of Earthquakes*, 410–411. Aristotle, *Meteorology*, Book I, 14.

He begins generally, that is, with all 'animated Bodies':

> Again, we find that the Powers and Faculties of the animated Bodies do continually exert a succession of differing Effects, and continually change the Figures and Shapes from one degree to another.[425]

Moreover, 'we see that there are many changings both within and without the Body'. Moving from animate bodies in general to species, Hooke asks, 'why then may there not be the same progression of the Species from its first Creation to its final termination?' Employing his fossils synecdoche, Hooke reasons that he has met with no 'Doctrine among the Philosophers, that is repugnant to' the supposition that 'the like States happen to all the Celestial Bodies, that is, to the Stars and Planets, that happen to the Individuals of any Species'. Thus, 'if the Body of the Earth be accounted one of the number of the Planets, then that also is subject to such changes and final Dissolution'.[426] Indeed, in his very first Discourse lecture, Hooke cites Seneca thus:

> And as in great Cities, now this House, now that House hangs tottering on Props; so on the great Face of the Earth, not this part fails, now that … They that promise to themselves all things fixt, surely never think that the very Ground we stand on is it self unfixt … the whole remains while each part changes and sinks into Ruine and Alteration.[427]

Even if someone has never experienced an earthquake, Hooke nonetheless expects that every*body* in his audience can comprehend the synecdochic relations owing to personal, sensual experience, for

> first we do find that all individuals are made of such a Constitution, as that beginning from an Atom, as it were, they are for a certain period of Time increasing and growing, and from thence begin to decay, and at last Die and Corrupt.[428]

Hooke had already presented this argument in 1668, which ties his

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425 Hooke, *Discourse of Earthquakes*, 435.
426 Hooke, *Discourse of Earthquakes*, 436.
427 Hooke, *Discourse of Earthquakes*, 311. Hooke provides this English'd Latin passage from the 'Preface to the 6th Book of [Seneca's] Natural Questions' (circa 65 CE).
428 Hooke, *Discourse of Earthquakes*, 435.

observations of and experiments on the rotting, liquefying and hardening processes of petrifaction together with his 'terraqueous globe' hypothesis, to defend his claim that the body of the earth used to be softer in the deep past, thus earthquakes could inflict more damage:

> from what I have instanced about Petrifactions and the hardning of several Substances, it seems very probable, that in the beginning the Earth consisted for the most part of fluid Substances, which by degrees have setled, congealed, and concreted, and turn'd into Stones, Minerals, Mettals, Clays, Earth, etc. And that in process of time the parts of it have by degrees concreted and lost their Fluidity, and that the Earth itself doth wax old almost in the same manner as Animals and Vegetables do[.][429]

Further, because 'Subterraneous Fuels do also wast and decay, [which] is evident from the extinction and ceasing of several Vulcans that have heretofore raged', Hooke speculates that earthquakes in the past were 'much more frequent and universal' and 'much more powerful'.[430] In contrast to Plot, for example, for whom extinction and changes to the earth's surface are signs of imperfection, and unlike Burnet, who conjectures from jagged coastlines and mountains that Earth was a smooth ovoid before Noah's deluge, whereas afterwards it was a broken world of ruins, Hooke inverts the theme of ruins and decay by arguing that decay and ruin are 'universal' natural processes – just like Seneca. This move allows him to compound his cyclical worldview with a world that, according to the Bible, must necessarily progress to a final 'dissolution' or 'decay'. According to Hooke, his 'Doctrine', with its mechanisms of earthly rot, change and ruin, first borrowed from Seneca, is not against 'the Omnipotence, Providence and Wisdom of the Creator' who saw fit to create the world and 'all individuals' with such a 'constitution';[431] employing synecdoche as an explanatory device again, Hooke concludes that 'in every part of their Life', 'individuals', just like the planets and the heavens, 'are in a continual change or progress, from more perfect, to more

[429] Hooke, *Discourse of Earthquakes*, 325.
[430] Hooke, *Discourse of Earthquakes*, 326.
[431] Hooke, *Discourse of Earthquakes*, 435, 311.

imperfect, there being a continual growth of Death and Decay to the final Dissolution'.[432] Thus, the cyclical yet linear path – that is, cyclical growth and decay or rise and ruin within a linear path to final dissolution – away from perfection is nature's way.[433]

Finally, these considerations of time's effects on matter in Hooke's doctrine enable him to enforce a pattern onto contingent past events. Stephen Jay Gould argued that natural laws can describe and predict repetitive natural phenomena – for example, rainbows and solar eclipses – but that natural history, with its lack of 'direct evidence' and its reliance on 'imperfect records' does not fall so easily into the realm of predictability and measurable things.[434] But Hooke's fossils, via 'inspection of the things themselves', 'an ocular Inspection and a manual handling, and other sensible examinations', provide a paradoxically tangible historical experience – a way to 'peruse, and turn over, and spell, and read the Book of Nature', to show that 'the Earth itself doth wax old almost in the same manner as Animals and Vegetables do', because history is present literally within fossils.[435] In this way, not only do ruins of myths and histories support the fragments of physical evidence according to Hooke, but vice versa – and he is fully aware of the implications. For example, in a historicist mood again, he considers that ''Tis not impossible but that there may have been a preceding learned Age wherein possibly as many things may have been known as are now, and perhaps many more,'[436]

> all the Arts cultivated and brought to the greatest Perfection, Mathematicks, Mechanicks, Literture, Musick, Opticks, etc. reduced to their highest pitch, and all those annihilated, destroyed and lost by succeeding Devastations.[437]

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432 Hooke, *Discourse of Earthquakes*, 435.
433 Hooke, *Discourse of Earthquakes*, 379–380.
434 Stephen Jay Gould, *Leonardo's Clams and the Diet of Worms* (New York: Harmony Books, 1998), 194.
435 Hooke, *Discourse of Earthquakes*, 338.
436 Hooke, *Discourse of Earthquakes*, 338.
437 Hooke, *Discourse of Earthquakes*, 328.

As William Poole observed, this also implies that 'the Rubbish, Ruins and Fragments of those'[438] mythologies, sacred histories, and civil histories that Hooke picks natural histories out of just happened to be preserved 'amidst general ruin and decline', and Hooke's 'theory of culture' rests on 'loss and not persistence'.[439] Yet it is a theory produced from the 'persistence' of what a fossil is according to Hooke; and what a fossil is in turn is crafted from Hooke's observations of and experiments upon these objects of nature; thus Hooke's cultural theory gains its power from his manipulations of nature. In Hooke's practice of instrument-mediated observation, fossils that appear static, which persist in retaining the identity of lost things amidst rot and ruin, are shown to be dynamic via mechanisms of petrifaction – a paradoxical synecdoche of nature's overall operations, of change, variety, and ultimately dissolution.

> This Objection [to extinction] therefore, I conceive, is of little validity against the Doctrine I have delivered ...[440]

Thus spoke Hooke in 1689. But Lister and Plot, as has been shown, had a different ontology, and as far as they were concerned, Hooke's words would continue to fall on deaf ears, nevertheless instigating further discourse. But an examination of Ray's published and private thoughts from 1673 to 1695 reveals that Hooke's defence did had an effect on him, certainly cementing Ray's beliefs about fossils, but perhaps also helping to change his mind on earthquakes as an explanation for the problem of place: how and why marine fossils ended up in mines and on mountains as high as the Alps. Hooke also forced Ray to confront the idea and possibility of extinction.

### 6.2 'PHYSICO-THEOLOGICAL'

In his 1673 work *Observations topographical, moral, and physiological*, a title that captures the hybridity in the making of a seventeenth-century fossil as well as Earth history, Ray sides with Hooke's 'most probable Opinion', agreeing that fossils 'were originally the Shells or Bones of living Fishes, and other Animals bred

[438] Hooke, *Discourse of Earthquakes*, 394.
[439] Poole, *The World Makers*, 113.
[440] Hooke, *Discourse of Earthquakes*, 436.

in the Sea' while simultaneously rejecting Hooke's ideas on extinction.[441] Using his own fieldwork on 'the stalks of *Equisetum*' (Chapter 5), Ray supports the organic origin hypothesis, stating that the '*Equisetum*' observations 'do abundantly convince and satisfie me'.[442] Moreover, when giving the 'Opinions of the best Authors concerning the Original and Production of them [fossils]',[443] Ray begins by citing Hooke's *Micrographia* liberally,[444] pointing out that Steno not only 'agrees exactly with him [Hooke]', but also that this 'was the general opinion of the Antients, insomuch that Steno saith, It was never made a Question among Them, whether such Bodies came from any place else but the Sea.' This ancient opinion 'is now received and embraced by divers learned and ingenious Philosophers, as in the precedent age by *Fracastorius*, and in the present by *Nicolaus Steno* and Mr. *Robert Hook*'.[445] It may seem bizarre that Ray refers to the organic 'Opinion' as ancient, since it agrees with the current definition of what a fossil is, which is perceived as a "new" hypothesis. If Hooke and Steno's hypotheses corroborate ancient claims, then at the other extreme the *lapides sui generis* 'Opinion' that Ray explains next by citing Lister's review of Steno's *Prodromus* seems to be "modern", for it is opposite to the ancient idea in several other respects already discussed. But this is not exactly so, since the *lusus naturae* or games of nature explanation has roots in Plato's forms and earthly copies.[446] (We will return to this notion of antiquity in the final chapter.) Ray ends with a third view, which attempts to combine the benefits of both Hooke and Lister's hypotheses; this compromise, that some fossils are of organic origin while others are spontaneously

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[441] John Ray, *Observations topographical, moral, and physiological* … (London: Printed for John Martyn …, 1673), 120.

[442] Ray, *Observations topographical, moral, and physiological*, Preface.

[443] Ray, *Observations topographical, moral, and physiological*, 113–114.

[444] Ray, *Observations topographical, moral, and physiological*, 120–125.

[445] Ray, *Observations topographical, moral, and physiological*, 120.

[446] Ray, *Observations topographical, moral, and physiological*, 128–129. Poole referred to this as a historiographical inversion, after noticing John Woodward calling the *lusus naturae* explanation the 'new Expedient', in Poole, *The World Makers*, 131–132. Woodward, *An Essay towards a Natural History of the Earth*, 40. Poole also points out earlier on that the *lusus naturae* explanation combines Neoplatonic and Paracelsian ideas of 'imitations and correspondences' (Pool, *The World Makers*, 116). See also Roger Ariew, 'Leibniz and the Petrifying Virtue of the Place', 35.

generated in the earth, fails according to Ray on account of lacking sufficient evidence to make distinctions about whether a fossil is of organic origin or generated in stone – yet later on, he inconsistently adopts this very position, gnawed by doubts, reluctant to commit to one extreme opinion or another.[447] Ray ends his remarks on fossils by reiterating that the first (Hooke's) view 'cannot be denied'.

> I propend to the first Opinion, as being more consonant to the nature of the thing, and could wish that all external arguments and objections against it were rationally and solidly answered.[448]

At this time, even though he announced himself to be on Hooke's side, Ray remained unconvinced that Hooke's arguments provided a 'rational and solid answer'. After quoting most of Observ. XVII from the *Micrographia*, Ray draws a breath, and points out that 'Against this Opinion lie two very considerable and material Objections, which I shall heer propound'.[449]

The 'considerable' part of the first objection – an objection to explanations about how fossils came to be where they are found – boils down to clashes 'with the Scripture'. According to Ray, if fossils are indeed the petrified remains of once living organisms, or their impressions, then it follows that the world was 'covered by the Sea, and that for a considerable time'.[450] By 'a considerable time', Ray means a stretch of time longer than is allowed by Mosaic chronology. Attempting to reconcile the hypothesis with the Bible hermeneutically creates 'material Objections'. For example, one might, like Steno, attempt to form a compromise by arguing that Noah's flood washed shellfish onto mountaintops, leaving them to rot and petrify after the waters receded; but Ray notes the 'material' problem, also pointed out by Plot and others:

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[447] Ray, *Observations topographical, moral, and physiological,* 130–131. Ray, *Three Physico-Theological Discourses* … (London: Printed for Sam. Smith, at the Princes Arms …, 1693 [second ed]) 127–162. Rudwick, *The Meaning of Fossils*, 81.

[448] Ray, *Observations topographical, moral, and physiological*, 131.

[449] Ray, *Observations topographical, moral, and physiological*, 125.

[450] Ray, *Observations topographical, moral, and physiological,* 125.

> If it be said that these Shells were brought in by the universal Deluge in the time of Noah, when the mountains were covered, I answer, that the Deluge proceeded from Rain, which was more likely to carry Shells down to the Sea, than to bring any upwards from it.[451]

In reply, one might quote from *Genesis*, adding that the deluge proceeded not only from rains, but also because the natural springs or 'fountains of the great deep were broken up',[452] which could have hurled shellfish onto mountains. But Ray, playing devil's advocate, rejoins that 'such a flood' would *scatter* shells all over 'instead of depositing them in great beds in *particular* places' or strata. Moreover, 'such beds seem to be the effect of those Animals breeding there for some considerable time'.[453] Ray leaves Hooke's earthquakes discourses, those that Hooke had presented before the Society up to 1673, for last: if fossils are found on mountains because mountains were once 'low places, and afterwards raised up by Earthquakes', then according to Ray it implies that *all* mountains were once low places since fossils 'are found upon so many Mountains'. But then 'the former difficulty will recur': that the earth was once completely covered by water for a long, deep time.[454]

'Besides,' Ray adds, 'the *Hypothesis* seems to me in itself improbable, for that though there be mention made in Histories of some such Mountains raised by Earthquakes, yet they are but few and if we consider highth or greatness, compared with those chains of high and vast Mountains,' such as the Alps, they are short by comparison.[455] Thus,

> if the Mountains were not from the beginning, *either* the World is a great deal older than is imagined or believed, there being an incredible space of time required to work such changes … *or* that in the primitive times and soon after the Creation the Earth suffered far more concussions and mutations in its superficial part than afterwards.[456]

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451 Ray, *Observations topographical, moral, and physiological,* 125–126.
452 *Genesis* 7:11 (KJV).
453 Ray, *Observations topographical, moral, and physiological*, 126. Italics added.
454 Ray, *Observations topographical, moral, and physiological*, 125–126.
455 Ray, *Observations topographical, moral, and physiological*, 126.
456 Ray, *Observations topographical, moral, and physiological*, 126–127. Italics added.

In other words, if there were more earthquakes 'in the primitive times and soon after the Creation', then the world is *not* older; if there were *not* 'more concussions', then 'the World is a great deal older than is imagined or believed'. In 1673, Ray concludes with Lister, and later Plot and others, that 'In general since the most antient times recorded by History, the face of the Earth hath suffered little change'.[457] But twenty years later, Ray uses the former conditional statement, which fits 'such changes' within Mosaic chronology, taking it upon himself to argue in support of seismic events for mountain-making, eating his words in the *Observations* with a long analysis of historical and recent accounts of earthquakes and eruptions in his *Three physico-theological discourses*.[458]

As the title attests, 'physico-' and 'theological' are two parts of a whole body of knowledge: natural theology. And here, as in his other works, Ray attempts to show that the physical appearance of the earth provides ample evidence of God's plan and providence. Yet his worries about noticing, cataloguing, and classifying order in the world skew his studies of nature towards the 'theological' part of the whole. That is, even though the two books – the Bible and the book of nature – remain inseparable according to Ray and almost all his contemporaries where the subject of Earth history is concerned, he leans more towards the 'Theological' side, using his skills and experience as a botanist and zoologist, thus his background knowledge and particular interest in taxonomy over 'speculative' natural philosophy, to support rather than challenge 'the historicity of *Genesis*'.[459] Nevertheless, although Ray promotes the metaphysical image of an interventionist God, his rejection of Noah's flood as an explanatory device for fossils (after considering it as a possibility), and his need to persuade his readers that the Deity designed Earth as an ordered home for mankind, hints at the roots of eighteenth century

[457] Ray, *Observations topographical, moral, and physiological*, 126.

[458] Ray, *Three Physico-Theological Discourses,* unpaginated, 10-22, 163-165, 181-290. Ellen Tan Drake argues that Ray plagiarised Hooke: Ellen Tan Drake, *Chapter 7: Plagiarism or Paranoia?*, in Ellen Tan Drake, *Restless Genius: Robert Hooke and his Earthly Thoughts* (Oxford and New York: Oxford University Press, 1996).

[459] Charles Raven, *John Ray, Naturalist* (Cambridge: Cambridge University Press, 2009 [1942]), 419.

deism. That is – to sketch this epistemological transformation briefly – the seventeenth century dual approach to God via the Scriptures and nature, which would in the eighteenth century undergo incomplete metamorphosis into a reliance on nature for revelation and a rejection of the Scriptures as an inconsistent and therefore unreliable source of knowledge.[460]

Now, even though Ray shares Lister and Plot's cultural tradition and thus their taxonomical approach to the production of natural knowledge, and although he initially sides with them in 1673 on the status of the earth's superficies, in 1693 he publicly rejects their fossils ontology on theological grounds. In the *Three Physico-Theological Discourses*, alarmed at the implications of Burnet's claim that the mechanism of Noah's flood was caused by accidental natural causes (in other words, not supernatural ones), Ray's worry is that the *lapides sui generis* opinion on what a fossil is will serve only to support the claims of 'Atheists' (atomists), because down the slippery slope it could follow that animals are productions of accidental, natural causes too.[461]

> If we adhere to their Opinions who hold them to have been original Productions of Nature, *in imitation only* of the Shells and Bones of Fishes: We put a Weapon into the Atheists hands, affording him a strong Argument to prove that even Animals themselves are casual Productions [of chance], and not the effects of Counsel and Design.[462]

For Ray, mere resemblance or 'imitation only' equates to a contingent world lacking divine providence or order, a world knowable only probabilistically, leading not to a final dissolution or conflagration, but who-knows-what. One can infer from Ray's work, especially his pedantic studies of plants, that there would be little point in attempting to classify and catalogue the flora and

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460 Davies, *The Earth in Decay*, 102–103, 159. See also Wayne Hudson, Diego Lucci, and Jeffrey R Wigelsworth (eds), *Atheism and Deism Revalued: Heteredox Religious Identities in Britain, 1650–1800* (Surrey, England: Ashgate, 2014).

461 Ray, *Three Physico-Theological Discourses*, unpaginated. See also John Woodward, who wrote his own animadversions against Burnet in this regard: Woodward, *An Essay towards a Natural History of the Earth*, 165.

462 Ray, *Three Physico-Theological Discourses*, unpaginated. Ray repeats his worries on atheists using fossils as weapons in the war of chance versus intelligent design and teleology on pages 133–134.

fauna of a 'strange' and estranging world that works at whim. This is also why he latches onto Hooke's teleological, Aristotelian remark in the *Micrographia*, repeated in a couple of the latter's discourses on earthquakes, that nature does nothing in vain. The *lusus naturae* 'Opinion' robs 'formed stones' of anything beyond a superficial function or purpose – that is, it robs them of meaning. And Ray's worldview is constructed on foundations of meaning not mechanistic causes. Thus, unlike Hooke, Ray's concern, then, is not how to "read" fossils to develop a history of the earth from the earth, but rather to answer any 'vulgar' reader who might ask *'What reference hath the consideration of Shells and Bones of Fishes petrified to Divinity?'*[463] This is a real question for him as a preacher of sermons on topics such as the deluge and the dissolution of the world, pondering how the problem of fossils fits into such natural Earthly changes, and attempting to write them into these changes as well as into sacred history and vice versa. (It also did not go unnoticed by Ray that the novelty associated with fossils in discourses on the history of the world might help his book sales.)[464] Similarly, Ray's interest in earthquakes and eruptions is not primarily 'physico-' (or pecuniary), but 'theological', as his gradual inversion of the theme of ruins reveals. Thus, in both respects, Ray's work makes a perfect foil to Hooke's.

To recapitulate, for Burnet, torn coastlines and jutting shards of mountains are empirical evidence of the earth's imperfection; Hooke inverts the theme of ruins by arguing that decay and ruin are 'universal' *natural* processes. In 1691, Ray was still stuck between siding with Hooke on fossils and with Lister and Plot on the earth's static topography:

> the Earth, which is the basis of all Animals, and as some think of the whole Creation, ought to be firm, and stable, and solid, and as much as it is possible secured from all Ruins and Concussions.[465]

Namely, an Earth 'secured' from earthquakes and eruptions – with most

[463] Ray, *Three Physico-Theological Discourses*, unpaginated.
[464] John Ray, in Charles Raven, *John Ray, Naturalist* (Cambridge: Cambridge University Press, 2009 [1942]), 431–432.
[465] John Ray, *The Wisdom of God Manifested in the Works of the Creation* (London, 1691), 137.

accidents caused by human agency. Yet the very next year, Ray published a 'Digression' of *Miscellaneous Discourses Concerning the Dissolution and Changes of the World* (henceforth *Misc Disc*), expanding it into the *Three Physico-Theological Discourses* (henceforth *Three Discourses*) the year after that. In the earlier *Misc Disc*, Ray speculates for the first time on the role of earthquakes and volcanoes in the production of mountains. However, although Ray's two discourses are almost alike when it comes to the topics of seismic and volcanic activity, they differ importantly on his treatment of nature's ruins, again underscoring his need to reconcile the physical and theological underpinnings in his ruminations on the present state of the earth's superficies and fossils. In the *Misc Disc*, Ray provides an apologia for the diversity and asymmetry of mountains. It should be noted that the question of mountains, specifically whether they formed part of the earth's topography from the beginning, had been asked and answered well before Ray decided to join the discourse. For example, in 1592, the Jesuits at the college of Coimbre decided that the earth 'had been created with mountains because of their usefulness and beauty'.[466] Ray recycles this answer in his response to the worry, and Burnet's speculative cosmogony, that 'it may be objected, that the present Earth looks like a heap of Rubbish and Ruines; And that there are no greater examples of confusion in Nature than Mountains singly or jointly considered', from which it follows 'that there appear not the least footsteps of any Art or Counsel, either in the Figure and Shape, or Order and Disposition of Mountains and Rocks', Ray responds thus:[467]

> the present face of the Earth with all its Mountains and Hills, its Promontories and Rocks, as rude and deformed as they appear, seems to me a very beautiful and pleasant object, and with all the variety of Hills, and Valleys,

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466 Glacken, *Traces on the Rhodian Shore*, 376.

467 Ray, *Three Physico-Theological Discourses*, 35–36. Also see John Ray, *Miscellaneous Discourses Concerning the Dissolution and Changes of the World* … (London: Printed for Samuel Smith …, 1692), 165. (Henceforth *Misc Disc*.)

> and Inequalities far more grateful to behold, than a perfectly level Countrey without any rising or protuberancy, to terminate the sight[.][468]

He recycles this same defence in the *Three Discourses*, with an important addendum: not only are 'rude and deformed' mountains 'very beautiful and pleasant' natural objects to behold, but ruin, devastation and decay are part and parcel of 'Providence' – to 'balance' and 'keep all things in an *AEquilibrium*; so that it is said of the Sea, that *what it gains in one place, it loses in another* [that is, tides] … a long Drought in one Place is compensated probably at the same time by as long a rain in another'.[469] This is Ray's cautious attempt to solve the paradox created by a world of ruins and loss that simultaneously operates on providence.

Moreover, Ray reminds his readers that 'the variety of Hills, and Valleys,' allows for diverse animals, plants and minerals, all of which are 'excellently ordered and provided by' the 'Wise Creator'.[470] Glacken argues that this '*newer* vision of the earth was best grasped' by Ray, who rejected the belief that the decay of morals in man, a result of the original sin, was mirrored in nature by the earth's decay.[471] Thus, by painting nature in his own image of metaphysics, Ray reaches the same conclusion as Hooke on nature's ruins: they are not signs of imperfection. But where Hooke inverts the theme to support a new Earth history with an ordered cyclical hypothesis that he needs to constrain within a linear chronology consistent with the Scriptures, Ray does so to protect 'Divine Providence', and the established order of sacred history, from chance or 'Accident'. Similarly, Ray's fossils compromise, discussed earlier, also serves as a failsafe for providence; and together, providence and the compromise serve to prevent extinction. Although some scholars have noted Ray's eventual acceptance of the idea that some species have become extinct,[472] according to Ray, this is not the same thing as extinction,

[468] Ray, *Misc Disc*, 165–166.
[469] Ray, *Three Physico-Theological Discourses*, 281. Italics added.
[470] Ray, *Three Physico-Theological Discourses*, 36–44, 45.
[471] Glacken, *Traces on the Rhodian Shore*, 379. Italics added.
[472] See, for example, Raven, *John Ray, Naturalist*, 428.

even though he examines it thoroughly as a rational possibility.

### 6.3 'Lost or destroyed'

Now, the second objection noted by Ray, in the 1673 *Observations,* is to extinction, and because of this it is particular to Hooke's earthquakes doctrine. 'Among these petrified Shells are many sorts, which are not at this day *that we know of* anywhere to be found'.[473] Implicit in this statement, again, is Ray's compromise: although these fossils are nowhere to be found at present, it does not follow that they are extinct; they could be extant somewhere far offshore or in unexplored depths. Moreover, taking into consideration the intellectual challenges posed by attempting to create knowledge locally with foreign natural objects, Ray proposes in the third edition of the *Three Discourses* (1713) that because 'force of winds or stress of weather' move objects – 'several East-India fruits have been brought over the vast Ocean and cast upon the Western Isles of Scotland' – this may explain why ammonites are 'altogether strangers to our seas' better than 'the general Deluge' explanation, which he refutes.[474] But the possibility of extinction would harry Ray well into the later years of his life, so much so that he would simply cut-and-paste the objection from the *Observations* into the *Three Discourses* of 1693:

> If it be said, that these species be lost out of the World: that is a position which Philosophers hitherto have been *unwilling to admit*, esteeming the destruction of any one Species to be a dismembring the Universe and rendring it *imperfect*.[475]

In the *Observations*, Ray provides the same reason published by Plot a few years later in *Oxford-shire*: that 'they [philosophers] think that the Divine Providence is especially concerned to preserve and secure all the works of the Creation'.[476] Nevertheless, in the interim between 1673 and 1693, Ray had attempted to compromise with Hooke's extinction hypothesis by coupling the

473 Ray, *Observations topographical, moral, and physiological,* 127. Italics added.
474 John Ray, *Three Physico-Theological Discourses …* (London: Printed for William Innys …, 1713 [third edition]), 156.
475 Ray, *Observations topographical, moral, and physiological*, 127. Italics added.
476 Ray, *Observations topographical, moral, and physiological*, 127.

early modern problem of objects and knowledge crisscrossing 'over the vast Ocean' with the following hypothetical question: what if 'the destruction of any one Species', instead of a whole genus, is permissible? For example, if a species of shellfish or nautilus had become extinct, but the genus of shellfish or nautilus had not undergone extinction.[477] Ray argues that so long as a genus is not 'destroyed', even though a species may be 'lost', it is never actually 'destroyed', so it is not extinct. The difference is that lost describes a part and destroyed a whole.

In an undated paper entitled '*Mr.* Ray *of the Number of Plants*', he begins by making the claim that it is 'morally impossible' to 'determine precisely what *Number of Plants* there are in the World'.[478] Charles Buck's nineteenth century theological dictionary, popular enough to enjoy several editions, defines 'moral impossibility' as 'a very great or insuperable difficulty; opposed to a natural [physical] impossibility'.[479] Closer to Ray on the timeline, Thomas Dyche's *A New General English Dictionary* (1740) provides distinctions between '*moral* certainty', '*moral* impossibility' and '*moral* actions', where

> proof of the being of an action that depends upon the evidence of the beholders, is called *moral* certainty; and so where there is almost an insuperable difficulty to be overcome, it is called a *moral* impossibility … and those acts that are done by an agent that can choose or refute, and so are rewardable or punishable, are called *moral* actions.[480]

According to Sven K Knebel, this "moral modality" of certain impossibility stems from the seventeenth-century Jesuit moralist distinction between what is

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[477] Ray, *Observations topographical, moral, and physiological*, 127. Ray usually uses the words 'species' and 'genus' as in the example given here; however, in his *The Wisdom of God Manifested in the Works of the Creation*, 4–5, he seems to borrow to Lister's taxonomical system.

[478] John Ray, '*Mr.* Ray *of the Number of Plants*', in William Derham (ed), *Philosophical Letters …* (London, 1718), 344. According to D C Gunawardena, Ray's essay was not first published in the *Philosophical Letters* (referenced here); rather, Gunawardena claims that, based on internal evidence, the essay was published some time between 1673–1682: D C Gunawardena, 'Contributions to a biography of John Ray (1627–1705)' (*Proceedings Linnean Society London*, Volume 148, Issue 2, March 1936, 71–73), 71.

[479] Charles Buck, *A Theological Dictionary* … Vol. 2 (London: Printed by Knight and Compton …, 1802), 168. Charles Buck, *A Theological* Dictionary … (Philadelphia: Published by Joseph J Woodward, 1835 [Stereotype edition], 390.

[480] Dyche, *A New General English Dictionary*, MOR.

*physically* versus *morally* possible and impossible – an addition to the thirteenth-century distinction between what is *physically* versus *logically* possible or impossible. To borrow Knebel's explanation, recast in terms of probability, and apply it to Ray's claim, if '"morally" … is no deontic modifier,' but simply means "virtually" or "actually", then 'morally possible (morally contingent) means that' one's ability to demonstrate the number of plants in the world 'actually has been or will be the case sometimes, no matter how often' whereas morally impossible means one's ability to demonstrate the number of plants 'actually is never the case'.[481] For example, Ray can never demonstrate with certainty the number of plants even though he can provide a probabilistic opinion. Likewise, Ray claims that it is impossible to accept extinction on authority, or to promote oneself as an authority figure of the same, since one can never possibly acquire the amount of knowledge necessary to do so. In this context, though moral possibility is incompatible with the principle of plenitude[482], moral impossibility is again meant to serve Ray's notions on plenitude and providence by negotiating contingency into his argument, allowing it as a negligible or impossible possibility, and thus entangling it with the ethical considerations that come with his own '*moral* actions'.

Continuing, Ray adds that before one can 'make any conjecture about' the number of plants, it is necessary 'to debate' the two following questions: '1. Whether there have been or are yearly any new Species produced besides what were at first created? 2. Whether there have been, or may be any Species lost or destroyed?'[483] Ray's responses are designed to promote his idea of providence creating equilibrium or 'proportion' and 'balance' with both 'Productions' and 'Destructions' by denying that either 'cause' is

[481] Sven K Knebel, 'The Renaissance of Statistical Modalities in Early Modern Scholasticism', in Russell L Friedman, and Lauge O Nielson (eds), *The Medieval Heritage in Early Modern Metaphysics and Modal Theory,* 1400–1700 (The New Synthese Historical Library, Vol. 53: Kluwer Academic Pub., 2003), 236. Also see Sophie Roux, 'Everything You Always Wanted to Know About the Summa Quadripartita that Descartes Never Wrote' (*Journal for Early Modern Studies*, Research Centre for the Foundations of Modern Thought, University of Bucharest, 2016, 5), 171–186.

[482] Knebel, 'The Renaissance of Statistical Modalities in Early Modern Scholasticism', 235.

[483] Ray, '*Mr. Ray of the Number of Plants*', 344

'accidental'.

> For if either of these [propositions] be affirmed, in vain would it be to enquire the number of the Plants; it being uncertain, and variable every Year, and that possibly to a very great excess, or defect. For the causes of these Destructions and Productions being accidental, there is no reason why one should exactly, or in any near proportion, balance and compensate the other.[484]

Just as Ray claims that mountains are not the products of accident, arguing that they are caused by the careful and necessary hand of providence to maintain equilibrium, and just as he argues that mere resemblance implies accident over order, here he attempts to 'prove' that providence maintains order in the world of plants. Whether Ray penned *Number of Plants* before or after the *Observations*, he applies his thoughts on plant species, genus and extinction in the former essay to ammonites in the latter work.

To expound, Ray's answer to the first question, that is, 'Whether there have been or are yearly any new Species produced besides what were at first created?', is the commonplace explanation that no new plant species have spawned since Creation, but that environmental 'accidents' such as climate, soil and nutrients affect the physical appearance of plants. Thus, in the same manner that one would not jump to the conclusion that 'an *European*, and an *Ethiopian*, are two Species of Men, because one is black and the other white', so too should one withhold belief that plant diversity based on superficial changes such as colour signifies a new species.[485] Ray's response to the second question is more interesting, because he struggles to craft a strong argument, and the weaknesses reveal his real worries. Further revealed is how the same means can create contrary images of nature, owing to different ways of knowledge-making, which train the imagination as well as one's suspension of disbelief. Although 'it is absolutely, and physically possible' that species have been 'lost or destroyed', it is nevertheless 'highly improbable, that

[484] Ray, '*Mr. Ray of the Number of Plants*', 344.
[485] Ray, '*Mr. Ray of the Number of Plants*', 345.

any Species should be lost' and it is '*impossible morally* that any Man should be *sure*' that species have been '*destroyed*'.[486] From the insertion of physical possibility into his second response, it may seem as though Ray has changed his mind about extinction, but this distinction between physical and moral possibility serves as yet another stepping stone to his rejection of the notion. As discussed earlier, for Ray, 'lost' and 'destroyed' carry different connotations and define different actions with respect to extinction.

Employing his empirical expertise as a botanist to make a move from concrete local knowledge to a hypothesis that accounts for plant species globally, in order to challenge Hooke's argument that one causal factor of extinction is 'Animals and Vegetables peculiar to certain places, and not to be found elsewhere',[487] Ray reasons that because he has 'not observed in *England* any one Plant so proper to one Place,' but has 'found the same either beyond Sea, or at least in several Places of this Island', he 'doubt[s] not but whatever grows naturally here may be found in divers Places of the same Latitude, or Temper, beyond the Seas'. Thus he 'can hardly persuade' himself 'that there is any one local Species of Plants in the World', meaning 'so proper and peculiar to one individual Place as not to be found elsewhere'.[488] Further, as mentioned, extinction is '*impossible morally*' (and physically, relative to Ray or any other human being), because

> no Man can be sure that there is any one *local Plant* in the World, unless either he himself hath visited every little spot of the whole Earth, or have information from intelligent Persons, that know all Plants, in all Countries, *both which are utterly impossible*[.][489]

Again, it is impossible to be in possession of enough worldly knowledge to be able to assert with authority and certainty that 1) a species of plant thought to be extinct does not exist in some remote unexplored region, or that 2) it has been utterly wiped off the face of the earth in all regions where it was, or might

486 Ray, '*Mr. Ray of the Number of Plants*', 350. Italics added.
487 Hooke, *Discourse of Earthquakes*, 327.
488 Ray, '*Mr. Ray of the Number of Plants*', 350.
489 Ray, '*Mr. Ray of the Number of Plants*', 351. Italics added.

have been, previously found – even if it *is* extinct. To put it in Ray's words, 'But if there are no *local Plants*, as I am confidently persuaded there are not, then it is next to impossible that Causes should concur to destroy any one Species out of the World;'[490]

> or if they did, that any Man in so vast a Place as the Earth is, so great a part of it also Desart, or inhabited by barbarous Nations who mind not these things, should ever get Advice, or come to the knowledge of it.[491]

Notice that Ray's argument rests on his being 'confidently persuaded' that 'there are no *local Plants*' in the world, even though he himself denies 'that any Man in so vast a Place as the Earth' can ever hope to make such knowledge claims on nature 'confidently'. If it is possible, as Ray claims in this final line of his *Number of Plants*, that a species is extinct, but that no 'Man … should ever … come to the knowledge of it', then it is also possible to make the assumption that Ray may never 'come to the knowledge' that there exist *'local Plants'* somewhere 'in so vast a Place as the Earth'. Here Ray forgets to practise the scepticism that he preaches.

This very scepticism, and Ray's deeply felt sense of estrangement from nature owing to the vastness of Earth and 'strange' fossils, also forms the spine of his fossils compromise, which he uses to reject the *lusus naturae* explanation while at the same time objecting to extinction. The lack of peculiarity ensures that even if a species is 'lost' locally, it is not 'destroyed' globally.[492] Thus Ray conjectures that 'supposing there be such *local Plants',*[493]

> though they were at present utterly extirpated by the Hand of Man, or any Accident, yet the Seed, or at least seminal Tinctures remaining in their original and native Soil, when the present obstruction is removed, the Earth will be apt to put forth the same Plant again[.][494]

Pondering the problem of ammonites in the *Observations*, Ray is fuelled by the

[490] Ray, '*Mr. Ray of the Number of Plants*', 350–351.
[491] Ray, '*Mr. Ray of the Number of Plants*', 351.
[492] Ray, '*Mr. Ray of the Number of Plants*', 350.
[493] Ray, '*Mr. Ray of the Number of Plants*', 350.
[494] Ray, '*Mr. Ray of the Number of Plants*', 350.

same fears, and relies on the same argument strategy to quell them: supposing that 'some few Species [of 'Shell-fishes'] might be lost, it is very unlikely that so many should [be], and still more unlikely that such as were so diffused all over *Europe* and found in so many places' should be lost. His perpetual worry is not that 'some few Species' should be lost, but 'that a whole *Genus*, of which there were so many several Species, and those scattered in so many distinct and from each other remote places, should be so utterly extinct and gone'.[495] Again, this is a weak argument, and reveals that Ray's anxiety stems from tensions between what he categorises as parts and wholes, and the possibility that a whole – a genus – may be extinct.

For example, 'Serpentine Stones or *Cornua Ammonis*' (or '*Ophiomorphites*') are 'supposed originally to have been *Nautili*', Ray has 'seen five or six distinct Species [of them]' (though 'doubtless there are yet many more') and some have been found 'about a foot [in] Diameter, far exceeding the bulk of any Shell-fish now breeding or living in our Seas'. Although this size discrepancy between living nautili and some ammonites at first leads him to speculate that '*Ophiomorphites*' might be 'of a distinct *Genus*', later on in the third edition of the *Three Discourses* (published posthumously in 1713), Ray inserts the following addendum:[496]

> Upon farther Consideration, I find Reason to agree with Dr. *Hook*, and other Naturalists, That these *Cornua Ammonis* are of the same *Genus* with *Nautili,* and differ only in Species. But yet these *Species* are subaltern *Genera*, each having divers Species under it.[497]

It is possible that sometime between the second and the third edition of the *Three Discourses*, Ray realised that he must necessarily agree with Hooke on the origin of ammonites, for if he were to maintain the proposition that they are of a different genus to nautili, then based on his own arguments in the *Number*

[495] Ray, *Observations topographical, moral, and physiological*, 127.
[496] Ray, *Observations topographical, moral, and physiological*, 127; Ray, *Three Physico-Theological Discourses* (1693), 153, versus Ray, *Three Physico-Theological Discourses* (1713), 155.
[497] Ray, *Three Physico-Theological Discourses* (1713), 155.

*of Plants* and elsewhere, he would be forced to conclude that an entire genus had been accidentally 'destroyed'.

On the one hand, Ray has no explanation for the extinction of a whole genus. Because he takes the deeply entrenched notion of 'Providence' as an axiom, thus striving to free it of all contradictions like ruin and decay, it is unimaginable to him that a genus could be 'destroyed', since it implies not only that the genus – namely, physically characteristic flora or fauna with the ability to reproduce – no longer exist, but that the 'Seeds', created during the first 'six days', had been eradicated from the earth.[498] On the other hand, Ray is willing to allow the so-called extinction of parts of a genus, namely, species, because he has an explanation for why part of a whole cannot be 'destroyed' even if it is 'lost'. Here, too, he transfers his accumulated observations of plants, and their seeds in particular, coupled with his usual theological boundaries, from 'A Discourse on the Seeds of Plants' to fauna and fossils like ammonites in the *Three Discourses*:

> as there neither is nor can be any new Species of Animal produced, *all proceeding from Seeds at first created*; so Providence without which one individual Sparrow falls not to the Ground, doth in that manner watch over all that are created, that an entire Species shall not be lost or destroyed by any Accident.[499]

Similarly in the *Number of Plants*, infinitesimal 'Seeds' can regenerate a species 'lost or destroyed by an Accident'. But although Ray is indebted to Aristotelian ideas about generation, it would be wrong to categorise his concept of seeds as Aristotelian. Likewise, Ray's 'Seeds' should not be confused with Neoplatonic "plastic" virtues, like those favoured by proponents of the *lusus naturae* view, which he often criticises the same way as Hooke.[500] Ray's approach forms a tense structure from pieces of the Aristotelian idea, his own

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[498] John Ray, 'A Discourse on the Seeds of Plants', in Birch, *The History of the Royal Society of London*, Vol. 3, 163, 173 (162–169).

[499] Ray, *Three Physico-Theological Discourses* (the 1693 edition, unless stated otherwise), unpaginated. Italics added.

[500] For Aristotelian versus Neoplatonic seeds, also see Rappaport, *When Geologists were Historians*, 106–107. Italics added.

'ocular observations', as well as studies of Hooke's and Antoni van Leeuwenhoek's microscopic observations.[501]

### 6.4 'Seeds'

Ray's 'ocular observations' coupled with his interpretations of the instrument-mediated observations of his contemporaries offer another part of his solution to the problem of extinction. Continuing with the frustrating problem of ammonites, Ray admits,

> if these Bodies were sometimes the Shells and Bones of Fish, it will thence follow, that many Species have been lost out of the World, for example, those *Ophiomorphous* ones, whose Shells are now called *Cornua Ammonis*, of which there are many Species, none whereof at this day, appear in our or other Seas. So far as I have hitherto seen, heard or read.[502]

Ray's worry stems from the possibility that 'many Species have been lost' – because it implies a natural catastrophe or many, and thus creates the problem of having to account for seemingly no differentiation between what is lost versus what is spared. After repeating his fossils compromise, Ray adds, 'though they [species of ammonites] may have perished or by some Accident been destroyed out of our Seas, *yet the Race of them may be preserved and continued still in others* [of the same genus]'.[503] To support this claim Ray argues by analogy:

> though Wolves and Bevers, which we are well assured were sometimes native of England, have been here utterly destroyed and extirpated out of this Island, yet there remain plenty of them still in other Countrys …[504]

Recall, Ray made this observation in his essay on the *Number of Plants* as well, where he invoked providence to argue that even if an accident were to destroy a species of plant locally, it would not do so globally. For his 'Seeds'

[501] Ray, 'A Discourse on the Seeds of Plants', in Birch, *The History of the Royal Society of London*, Vol. 3; Ray, *Three Physico-Theological Discourses*, 50–61.
[502] Ray, *Three Physico-Theological Discourses*, unpaginated.
[503] Ray, *Three Physico-Theological Discourses,* unpaginated.
[504] Ray, *Three Physico-Theological Discourses,* unpaginated.

explanation, Ray adopts the early modern concept of preformation together with new studies of 'Animalcules' – microscopic objects produced by instrumentalised experimental observation.[505] Yet even with his fossils compromise, and his attempts to uphold belief in a divine order via a naturalist's observations, classifications and so on, Ray acknowledges that gaps and inconsistencies riddle his account, and confesses that his explanation still fails to 'fully satisfie' him ('much less then am I likely to satisife others').[506] Even so, although his thoughts on ammonites waver, they remain resolute when it comes to 'Seeds'.

In 1674's *Seeds of Plants*, Ray notices that 'Nature observes not proportion of magnitude between seeds and the plants that come of them'. That is, often a small seed produces a great plant, and vice versa – the 'scarlet oak' grows to the size of a 'small shrub', but has seeds 'twice as big' as the 'great perennial mountain oak'.[507] Likewise in animals, nature does not 'always observe the same proportion of magnitude between the eggs' and the body – crayfish are smaller than lobsters, yet have bigger 'eggs'.[508] These observations on proportion and magnitude reveal that Ray is borrowing lenses from the new visuality brought about by the instrumentalisation of vision. Indeed, later in the *Three Discourses*, he draws yet again on Hooke's *Micrographia* (and Antoni van Leeuwenhoek's microscopic studies) when attempting to explain a notion on generation and *uninterrupted* lineage, to assist the imagination, and turn his readers into spectators of the hypothetical process of successive generations stemming from 'Seeds' produced during the original Creation. In this *Three Discourses* argument, proportion and magnitude serve the role of showing how it is physically possible for 'eggs' to contain invisible, infinitesimally small 'Animalcules' (literally minuscule animals), which play a mediating role

[505] Clara Pinto-Correia, *The Ovary of Eve: Egg and Sperm and Preformation* (Chicago and London: The University of Chicago Press, 1997), Chapter 1. Nicholas Russell, *Like Engend'ring Like: Heredity and Animal Breeding in Early Modern England* (Cambridge: Cambridge University Press, 2007). Gal and Chen-Morris, *Baroque Science*, Parts I and II.

[506] Ray, *Three Physico-Theological Discourses*, unpaginated.

[507] Ray, *'A Discourse on the Seeds of Plants'*, in Birch, *The History of the Royal Society of London*, Vol. 3, 162–163.

[508] Ray, *'A Discourse on the Seeds of Plants'*, 163.

by filling the gaps between physical reality and the imagination. However, although Ray makes similar moves to Hooke, his commitments and conclusions are different, as is his visuality.

Continuing with *Seeds of Plants,* Ray adds that there is also a 'great analogy between' how a 'seed' develops into a plant, and how an 'egg' develops into an animal: 'and in this respect, a man, as all other animals, may be said to live first the life of a plant'.[509] For

> likewise the seed or egg of a viviparous animal, when ripened, as it were, by the male, drops off one of the ovaria into the womb, where it lies for a while … and afterwards striking, as it were, root into the womb, fastens itself to it, and then probably draws at least part of its nourishment that way[.][510]

By 'ovaria', Ray means 'the bodies usually called testes faeminei,' stressing that 'whosoever will but *make use of his eyes* … must needs acknowledge [ovaria] to be nothing else but masses or clusters of eggs'.[511] As hinted above, these observations on proportion, as well as Ray's comparisons between the physiological development of plants and animals, form parts of his argument in support of providence in the *Three Discourses* of 1693. The principle of providence is Ray's primary reason for rejecting the concept of extinction.

To substantiate the conjecture that 'all Animals that have already been, or hereafter shall be, were at first actually created by God', and that no 'new ones' have been produced since, in the *Three Discourses* Ray relies on his extensive studies of seeds as well as both Hooke's and Leeuwenhoek's microscopic observations and experiments.[512] Supposing that the

> first generation from their first appearance had each of them (the Females I mean) its *Ovaria* or Clusters of Eggs, every one whereof had in like manner its Animalcule in it so that this second generation was also created in the

[509] Ray, '*A Discourse on the Seeds of Plants*', 168.
[510] Ray, '*A Discourse on the Seeds of Plants*', 168.
[511] Ray, '*A Discourse on the Seeds of Plants*', 168.
[512] Ray, *Three Physico-Theological Discourses*, 51.

> first … and so on of all the generations that shall be as long as the World lasts.[513]

Ray is describing a sort of self-similar nesting like Russian dolls, and he is aware that it is hard to imagine spatially and temporally, and therefore historically. His solution is to transform the problem associated with imagining his description of lineage into a visual one by turning attention to the human eye as a limited instrument of vision; this way, he both promotes visual natural-philosophical thinking in his spectator-readers, and replaces the eye with microscopic vision,[514] thrusting the imagination into the micro-world of animalcules. Ray is aware that it is difficult 'to *conceive* such a small portion of matter to be capable of such division, and to contain such an infinity of parts' that are beyond the limits of the human eye, which in turn limits the imagination. He attempts to assist his readers to render these forms in the mind's eye, first by appropriating and paraphrasing Hooke's opening observation in the *Micrographia* on points as a visual explanatory device for 'Eggs':[515]

> our sight doth not give us the just magnitude of things, but only their proportion, and what appears to the Eye as a Point, may be magnified so, even by Glasses, as to discover an incredible multitude of parts.[516]

This idea, that 'Glasses' are tools allowing for shifts in scale or 'proportion', and reference frames, is a crucial methodological maxim of Hooke's practical geometry, and forms part of his answer to the question of infinitesimals.[517] But although Ray and Hooke share an epistemology of vision, they lack a common visuality because they approach nature from different local-knowledge systems anchored in opposing yet overlapping cultural circles. Ray's use of 'Glasses', 'proportion' and 'magnitude' is not meant to pull mathematics from physics; it is different from Hooke's microscopic identification of the 'Marks and

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[513] Ray, *Three Physico-Theological Discourses*, 51.
[514] For what Gal and Chen-Morris have dubbed 'the optical paradox', that is, the rejection of the observer for instrument-mediated empiricism, see Gal and Chen-Morris, *Baroque Science*, Part I.
[515] Ray, *Three Physico-Theological Discourses*, 51–52. Italics added.
[516] Ray, *Three Physico-Theological Discourses*, 51–52. Also see Hooke, *Micrographia*, Observ. I.
[517] Hodoba Eric, *The Capture of Spring*.

Characteristicks' of fossils; and it is also not like Hooke's analogical relation between insensible physical objects and insensible or remote history, where Hooke argues that just as the evidence gained from studies of microscopic objects is not and should not be rejected, historical testimonies 'are not to be rejected for their [smallish] bulk' (as discussed earlier). After a fashion, Ray takes Hooke's optical metaphor for historical investigation literally by simply citing his and Leeuwenhoek's observations, using them to create an order never before "seen" in nature that serves his own commitments. Ray expounds with 'Mr. *Lewenhoek's*' quantitative affirmation that 'some Animals there are so small, that is a grain of Sand were broken into 8000000 of equal parts, one of these would not exceed the bigness of one of those Creatures'; moreover, 'Mr. *Hook* proceeds further': some animals are 'so exceeding small, that Millions of Millions might be contained in one drop of water'. Taken together with Ray's fossils compromise, one can infer that there may be as many unknowns in a drop of water as there are in the sea – which threatens to become a thoroughly disorientating experience of nature. But with this combination of corroborating visual devices blurring the boundary between physical reality and fancy, Ray is in a position to focus his readers' attention by asking of them, not rhetorically, if the whole animal can be so miniscule, 'what shall we think of their parts containing and contained … their Ovaries or Eggs?'[518] By using proportion to shift the frame of reference from sensible, *physical* 'Seeds' and 'eggs' to *physical* and *imagined* microscopic 'Animalcules', Ray uses the animalcules as gap-fillers for the imagination to support the perception of lineage as an uninterrupted process of generation representing part of 'physico-theological' history. In this way, Ray attempts to make visible how it is physically possible that all life stems from the original 'Seeds' of the first Creation.

However, although Ray is happy for his suppositions to be instantiated by Leeuwenhoek's (and Hooke's) microscopic observations, he nevertheless notices a new threat to the principle of providence in Leeuwenhoek's 'new

[518] Ray, *Three Physico-Theological Discourses*, 52.

Opinion' that 'all Animals proceed from an Insect or Animalcule in the Male-sperm', which Leeuwenhoek had been promoting since at least 1679.[519] According to Ray, spermism contradicts 'the Wisdom and Providence of Nature'.[520]

> For supposing every Male hath in him all the Animalcules that he shall or may eject; they may, for ought I know, amount to millions of millions, and so the greatest part of them must needs be lost. Nay, if we take but one Coit, there must, in uniparous Creatures at least, abundance be lost.[521]

Leeuwenhoek is aware of these metaphysical difficulties and accepts them.[522] But Ray needs to agree with the 'Argument for the praexistence' or preformation of female 'Eggs', not the new 'Male-sperm' hypothesis, because 'if we suppose the *Foetus* to be originally in the Egg,' then there is no wasteful loss of 'Animalcules', which agrees with the doctrine of providence.[523] For Ray, it goes against reason that the body of man, created in God's image, has accidents purposely built in.

Yet two years later, in a private letter, cracks began to show in Ray's resolve because of the idea of extinction. Ray had struck up a correspondence with Edward Lhwyd – his junior by 33 years. Over the 1690s and early 1700s, as documented by the letters of both men, they developed an intimate friendship: 'in all the entercourse I have had with you …' Ray tells Lhwyd, 'I have discovered lesse of affectednesse, conceitednesse, pride or vain-glory then in almost any man of my acquaintance'.[524] Their friendship fostered an exchange of private thoughts that neither man would entertain publicly on fossils and extinction. As mentioned, Lhwyd succeeded Plot as the second Keeper of the Ashmolean Museum in 1691, and in November that same year, Ray attempted to turn him away from the *lusus naturae* opinion,

519 Ray, *Three Physico-Theological Discourses*, 60–61; Pinto-Correia, *The Ovary of Eve*, 69.
520 Ray, *Three Physico-Theological Discourses*, 61.
521 Ray, *Three Physico-Theological Discourses*, 61.
522 Pinto-Correia, *The Ovary of Eve*, Chapter 2.
523 Ray, *Three Physico-Theological Discourses*, 61.
524 John Ray, and Robert W T Gunther (ed), *MS. Ashmole*, 1817a, f. 218, Black Notley, July 18, [16]92, in *Further correspondence of John Ray* (London: Printed for the Ray Society, 1928), 230.

which Lhwyd had promoted as Plot's protégé. In a letter from Ray to Lhwyd dated 25th of November, Ray praises Lhwyd's fieldwork on 'formed stones' while at the same time advising him to consider that his observations (Lhwyd's) support rather than refute the organic origin of fossils.

> Your Discoveries in the subject of formed stones are very remarkable and instructive. Methinks what you have now found out should a little stagger and unsettle you in the opinion and belief that they are original productions in imitation of the shels and bones of fishes.[525]

Ray's description of the deliberately understated staggering and unsettling emotions that Lhwyd's 'Discoveries in the subject of formed stones' should elicit undoubtedly discloses Ray's own experiences. But Lhwyd would formulate a new fossils compromise between the inorganic and organic opinions, based on his own fieldwork, revolving around 'Seeds'. To sketch the idea in brief, in a long letter to Ray written in mid-1698, Lhwyd would propose that, for example, marine fossils found in rock are not *lusus naturae* resemblances, but rather, that they originate from the same 'seed' as the organisms that they appear to mimic, blown onto land and into crevices by winds and mists. According to Rudwick, Lhwyd's idea stems from hypotheses on generation, such as Leeuwenhoek's '"animaculist" concept of the embodiment of specific characteristics within the "seed" of each species',[526] but it is likely that Lhwyd is just as indebted to Ray's seed studies. In 1695, Ray, in another letter to Lhwyd discussing the origin of some 'Fern' fossils, would anxiously admit that on the organic origins 'side' of the debate

> there follows such a train of consequences, as seem to shock the Scripture-History of the novity of the World; at least they overthrow the opinion generally received, and not without good reason, among Divines and

[525] John Ray to Edward Lhwyd, 25 November 1691, transcribed by Helen Watt and Brynley Roberts, in *Early Modern Letters Online*, edited by Howard Hotson and Miranda Lewis, re-accessed 21/12/22.

[526] Lhywd, letter no. 200, in Gunther, *Early Science in Oxford*, Vol. XIV, 381–398. According to Rappaport, Lhywd's compromise was proposed independently by Joseph Pitton de Tournefort in Paris: Rappaport, *When Geologists Were Historians*, 106. See also Rudwick, *The Meaning of Fossils*, 84.

> Philosophers, that since the first Creation there have been no species of Animals or Vegetables lost, no new ones produced.[527]

Scholars in the past have successively interpreted this excerpt to mean that Ray privately harboured doubts on the Mosaic timescale owing to his belief that fossils are remains of organisms or their imprints. Certainly, Ray was long oppressed by doubts, and perhaps he kept his true beliefs on biblical chronology to himself. But to Lhwyd, he immediately clarifies that although from this concept of fossils follows 'a train of consequences, as seem to shock the Scripture-History', by 'novity' he means the world beginning with the creation of man. Everything before this time Ray refers to as the 'Antiquity of the Earth', and

> whatever may be said for the Antiquity of the Earth it self and bodies lodged in it, yet that the race of mankind is new upon the Earth, and not older then the Scripture makes it, may I think by many arguments be almost demonstratively proved[.][528]

Though this cheat (sacred history starts with mankind, not Earth) is designed to save the chronology of 'Scripture-History', the fundamental cause of Ray's anxiety is not a problem of chronology, because he is willing to compromise on "the Antiquity of the Earth"; rather, it is a problem of order. Fossils 'overthrow the opinion … that since the first Creation there have been no species of Animals or Vegetables lost, no new ones produced', disrupting not the length of the timescale, but its sequence. Further, the *lapides sui generis* opinion upsets Ray for similar reasons: resemblance or 'imitation only' *also* recasts the world in a mould without providence and order, a contingent world where studying nature means that one can only attain probabilistic knowledge of the divine. So, resemblance is as much of a problem as extinction. Finally, extinction is diametrically opposed to the ordered worldview that Ray takes great pains to promote and reinforce with his studies and published work, even

527 John Ray to Edward Lhwyd, 8 October 1691, transcribed by Helen Watt and Brynley Roberts, in *Early Modern Letters Online*, edited by Howard Hotson and Miranda Lewis, re-accessed 21/12/22.
528 Ray to Edward Lhwyd, 8 October 1691, in *Early Modern Letters Online*.

when 'reason' rebounds against 'the Scripture':

> it seems to me that the Earth it self, I meane this Terraqueous globe, is in a forced and preternaturall state, the Earth above the water, which is lighter then it, so that did not the Scripture tell us so much, one might by reason collect, that the Water was sometimes uppermost and covered all. But enough of this.[529]

Ray's compromises are attempts to bridge his estrangement from nature, and to solve the paradox created by a world of ruin, decay and loss that at the same time operates according to the principle of providence – even if he never resolves the contradictions within himself.

[529] Ray to Edward Lhwyd, 8 October 1691.

# CHAPTER 7: 'A SOLID BODY ENCLOSED BY PROCESS OF NATURE WITHIN A SOLID'

In an introductory interpreter's note to the reader, for his 1671 translation of Nicolaus Steno's *Prodromus* (1669), Henry Oldenburg elevates Steno's Earth studies to the stature of Robert Boyle's experiments on the air, thereby priming the reader for a spectacle similar to what they might have witnessed within the air pump. The *Prodromus*, then, is a treatise on new ways and means to examine and explore and experiment upon the earth. And yet, perhaps in a further attempt to foster intellectual relations between Steno's Tuscan treatise and the Royal Society's earthly interests, perhaps in his role as Secretary, Oldenburg recalls that Steno's studies – particularly his conclusion that petrifying juices are the causal agent behind petrified bodies – confirm Hooke's earlier work on the matter.

> Besides this, we cannot but take notice here of what was intimated a good while ago in *Numb.* 32 of the *Phil. Transactions*, p. 628. *viz.* That Mr. *Robert Hook* had at that time ready some Discourses upon this very Argument, which, by reason of the many avocations he hath met with in the rebuilding of the City of *London,* and his attendance on the *R. Society,* he hath not yet been able quite to finish for the Press.[530]

So, let us now use this opportunity to broaden the field of view from England to the Continent; from fossil bodies to the earth; and from Earth's quakes and subterraneous eruptions to those that, according to Hooke, cause pits on the surface of the moon. Because, as Oldenburg notes above, Hooke and Steno share not only similar ideas and commitments where fossils are concerned, but also on the earth and its motions. Thus, juxtaposing the differences in Hooke's and Steno's use of fossils as instruments in a '*historical* investigation of nature'[531]

[530] Henry Oldenburg, *The Interpreter to the Reader*, in Nicolaus Steno, and Henry Oldenburg (trans and ed), *The Prodromus to a Dissertation Concerning Solids Naturally Contained within Solids* … (London: Printed by F Winter …, 1671 [1669]), unpaginated. (Henceforth *Prodromus*.)

[531] Rossi, *The Dark Abyss of Time*, viii.

illuminates the differing doubts and motivations moulding the developments in their ideas on the history of Earth. For example, Hooke has no compunction about blurring the epistemological boundaries of the terrestrial and celestial realms to move his notions on earthquakes and eruptions from the local environment of the earth to other earth-like planets and vice versa. In the *Micrographia's* final observation, pointing his telescope up at the pits of the moon, Hooke proposes that they are the effects of internal motions '*analogus* to our Earthquakes',[532] creating a powerful visual pair with a trope borrowed from Galileo – the same trope used by Burnet to argue that both the earth and the moon are ruins. We will return to Hooke in the later sections of this chapter.

In contrast to Hooke's polymathic pursuits concerning the earth, Steno is foremost an anatomist, comparing the earth and its terrestrial fluids to the human body to formulate a thesis on the production of stones in and from fluids. Steno's turn to geology, so the popular story goes, happened in 1666 when his patron, Ferdinando II de Medici, the Grand Duke of Tuscany, sent him a shark's head to dissect. Upon noting similarities between the shark's teeth and fossils known as *glossopetrae* or tongue-stones, Steno argued that tongue-stones are the petrified remains of shark teeth – supporting Fabio Colonna's 1616 dissertation.[533] In turn, Steno's curiosity about the origin and formation of fossils led to a separate yet related interest: how a solid body, a fossil, becomes entombed within another solid; and to answer this, he turned his attention to the earth's 'Stony Beds' or strata.[534] Previous studies on Steno were often categorised (and analysed) according to subject matter: anatomical, geological, theological. But these categories leave little leeway for inter-relations, mergers of theory and experience, or hybrid thinking. Recently, some scholars have made efforts to show that Steno's work can only be understood properly as a whole: as Troels Kardel argued, Steno approaches the earth as an anatomist, dissecting its 'face' layer by layer.[535] Steno's anatomical

532 Hooke, *Micrographia*, 243.
533 Troels Kardel and Paul Maquet (eds), *Nicolaus Steno: Biography and Original Papers of a 17th Century Scientist* (Berlin Heidelberg: Springer, 2013), 168.
534 Davies, *The Earth in Decay*, 64.
535 Kardel and Maquet (eds), *Nicolaus Steno: Biography and Original Papers of a 17th Century*

knowledge, as well as his background beliefs, influence his imagination and perception of the sequences of events that changed the earth's face over time; therefore they shape the results that emerge from his examinations of fossils in particular and the earth in general.[536]

Similarly to Hooke, for Steno, the natural formation and structure of the Tuscan landscape is like an archaeological site: by carefully digging through layers of 'the *Present* state' of '*Toscany*', one 'may discover the *Former* state of the same' by recognising and ordering changes.[537] And Steno further configures the landscape in support of this idea, generalising it to the whole superficies of the earth. Thus, although we will keep returning to bodies throughout, our main interests here are not the finished products or fossils themselves, but the physical processes of their formation, and the epistemological difficulties encountered in Hooke's and Steno's ontology of fossils as non-mimetic objects or *re*-presentations.

Both Hooke and Steno manipulate and order the earth's superficies in theory just as it is manipulated in practice by human hands and art. So, it is important to consider how expert knowledge in one field contributes to the creation of meaning, and to the clarification and obfuscation of understanding, when applied to another. Paralleling Hooke and Steno reveals that their divergent ways of subjecting history to the investigative procedures of the new science nevertheless create convergent fossil ontologies, and notions on how nature works, in turn altering historical approaches to the study of the earth's superficies. Whereas Steno is content to restrain his investigations to the earth and to answer the problem of petrified bodies and place, Hooke's ambitions take into account all earth-like planets – such as the moon – their parts, wholes, motions and relations.

## 7.1 'Earthy matter'

'And the Lord God formed man of the dust *of* the ground, and breathed into

*Scientist* (Berlin Heidelberg: Springer, 2013), 169 –170, 205, 210–211.

[536] For more on Steno and sequences of events, also see Rossi, *The Dark Abyss of Time*.

[537] Steno, *Prodromus*, 96.

his nostrils the breath of life; and man became a living soul'.[538] Here is Steno's starting point. If it seems somewhat strange that the so-called 'Founding Father of Geology' was an anatomist before devoting himself completely to theology, and that he chose to study the earth as a human body, consider that Adam, the first man, was made and 'formed' of dirt, and that the human body, under certain conditions, produces crystals and stones.[539] Steno's second starting point, deciding upon his 'Laws of an *Analysis*', proves more problematic than the first: he needs to find a process of investigation which avoids 'seeding doubts' about his conclusions 'in the Examination of Natural things'. It is a difficult task. On the one hand, being too sceptical is paralysing: some philosophers are overly cautious of 'Demonstrations themselves, apprehending least in them also there should lurk the like error, as they have frequently discover'd in other Assertions'.[540] On the other, being too credulous is dangerous, and here, similarly to Hooke and his friend Christopher Wren, Steno chastises natural philosophers who 'esteem all those things true, which to them appear to be pretty and ingenious' – 'Patrons of Experience' who 'have either rejected even the most certain Principles of Nature, or have held the Principles invented by themselves for demonstrated'.[541] His solution is to appeal to background beliefs as a common ground 'acknowledged by all Schooles, as well by those, that are Lovers of Novelty, as those that are Addicted to Antiquity'.[542] Thus,

> I have deemed fit to urge that in *Physicks,* what Seneca hath often inculcated in *Morals;* where he affirms those Precepts of *Manners* to be the best, which are common to all, publick, and agreed upon by all of all the Families of Philosophers, *Peripateticks*, *Academicks, Stoicks, Cynicks*.[543]

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538 *Genesis*, 2:7 (KJV).

539 For Hooke's observations of urine crystals, see Hooke, *Micrographia*, 81; for Steno's explanation of crystal growth in the human body, see Steno, *Prodromus*, Chapter 19. Cecil Schneer, 'The Rise of Historical Geology in the Seventeenth Century' 264: 'The members [of the Royal Society] were familiar with the growth of stones from their interest in human calculi'.

540 Steno, *Prodromus,* 11, 13.

541 Steno, *Prodromus,* 14. For Hooke and Wren, see Hodoba Eric, *The Capture of Spring,* 14–15.

542 Steno, *Prodromus,* 14.

543 Steno, *Prodromus,* 14. According to Charles Raven, the debt owed by Judaism and thus Christianity to Stoic ethics is so great that it is 'absurd to regard the two strains [of ethics] as

Steno's mention of Seneca is no throwaway remark. First, Seneca's work was readily available in the seventeenth century, thanks to Justus Lipsius's 1605 edition. Second, for the Stoics, an understanding of physics was necessary for a comprehension of ethics.[544] In Stoic philosophy, without the intimate relation between physics and ethics one cannot attempt to live a meaningful life because 'the end of human life is "to live conformably with nature"'.[545] Thus, in Steno's inversion, a *moral* middle ground between 'Experiments and Reason' is necessary for a physics capable of establishing 'Causes' agreed upon by all philosophers.[546] This is similar to Ray's notions, discussed in the previous chapter, on physical versus moral possibility and impossibility, and moral actions: for Steno, the act of picking and choosing a physics 'common to all' is morally rewardable not only because it attempts to be 'common to all' and 'agreed upon by all', but also because it ensures that the practices and results of his Earth studies have an inbuilt ethic. In this way, the two – ethics and physics – are interdependent. Further, by tying Seneca's thoughts on common morals to a common physics – a version of the mechanical philosophy – Steno underscores some attractive Stoic aspects in this '*Physicks*' that he claims are 'acknowledged by all Schooles'.

For example, similarly to the Stoic idea of '*pneuma*', or to use Seneca's preferred term in Latin, '*spiritus*' – a universal plenum permeating all bodies, with tension or elastic properties accounting for change, and whose particles are in intimate contact – the first 'Cause' of change to 'Natural Motion' that Steno lists is 'From the Motion of the Fluid permeating all Bodies; and what

pure and distinct'. For example, Hillel's rules for Talmudic interpretation were derived from Greek rhetoric: Charles E Raven, 'The Biblical Attitude Towards Nature', in *Science and Religion: the Gifford Lectures, 1951, First Series, Natural Religion and Christian Theology* (Cambridge, Cambridge University Press, 1953), 30, and footnote 1 on the same page. Also see Oldroyd, *Thinking about the Earth*, 18.

544 Peter Barker and Bernard R Goldstein, 'Is Seventeenth Century Physics Indebted to the Stoics?' (*Centaurus*, Volume 27, Issue 2, July 1984, 148–164), 148, 150, 155. For a comprehensive account of Stoic physics, see Samuel Sambursky, *Physics of the Stoics* (London: Routledge and Kegan Paul, 1959). See also Michael J White, 'Stoic Natural Philosophy (Physics and Cosmology),' in Brian Inwood (ed), *The Cambridge Companion to the Stoics* (Cambridge: Cambridge University Press, 2006), 124–152.

545 White, 'Stoic Natural Philosophy (Physics and Cosmology),' in Brian Inwood (ed), *The Cambridge Companion to the Stoics*, 124.

546 Steno, *Prodromus*, 17.

things are this way produced, are said by Us to be produced Naturally'.[547] Steno's notion of a 'Body Natural' complements this claim. A 'Body Natural is an Aggregate of insensible Particles, pervious to Operations flowing from the Magnet, the Fire, and sometimes also from Light'. In a 'Solid, although the insensible Particles be moved sometimes, yet they scarce ever part from one another'; and 'in a Fluid the insensible Particles are in perpetual motion, and part from one another'.[548] But because the plenum permeates all, even though 'in a Fluid the insensible Particles … *part from one another*,' the particles of the plenum create a dynamic physical continuum of causality. Similarly to René Descartes, who according to Peter Barker and Bernard Goldstein purported 'that the fluid plenum itself could be composed of atomistic particles in such intimate contact that they excluded voids', the only qualities that Steno permits particles to possess in his moral physics are '*Extension*, and *Hardness*' – though he remains open to the possibility of other qualities, for ''tis a weak Argument, to deny that there is something else in a thing, because I do not observe it there'.[549] Finally, apart from the 'Natural Motion of the Fluid permeating all Bodies', 'Natural Motions can be changed' by two other 'Causes': '*Secondly*, from the Motion of Animals' – many of these motions are 'called *Artificial*', and '*Thirdly*, From the first and unknown Cause of Motion'.[550]

With this 'first' cause, Steno attempts to wed the Stoic elements of his physics to the scriptures by enforcing a relation between them with '*Artificial*' motion – changes caused by art. In doing so, he further forms relations

547 Steno, *Prodromus,* 16. Barker and Goldstein, 'Is Seventeenth Century Physics Indebted to the Stoics?', *Centaurus* 27(2):148–164 (1984), 154. Thomas G Rosenmeyer, *Senecan Drama and Stoic Cosmology* (Berkeley: University of California Press, 1989), 103. In Seneca, and Harry M Hine (trans), Seneca: *Natural Questions* (Chicago: The University of Chicago Press, 2010), Hine translates 'pneuma' as 'breath': '"Breath" in Stoicism is not another element, but a combination of air and fire, and it possesses "tension", which gives coherence and dynamism to everything in the world, animate or inanimate', 2–3.

548 Steno, *Prodromus,* 15.

549 Barker and Goldstein, 'Is Seventeenth Century Physics Indebted to the Stoics?', 157. Steno, *Prodromus,* 15. See also René Descartes, *Le Monde*, in René Descartes, and Stephen Gaukroger (ed and trans), Descartes: *The World and Other Writings* (Cambridge, UK: Cambridge University Press, 1998), 24: 'I conceive its [matter's] extension, or the property it has of occupying space, not at all as an accident, but as its true form and essence'.

550 Steno, *Prodromus,* 16.

between the 'first' and 'Artificial' motions with the 'Natural Motion' of the plenum. As pointed out by Stefano Miniati, Steno's notion of 'the first and unknown Cause of Motion', which Steno explicitly states is God (for him) later in the paragraph, is unlike Descartes's: 'Steno's God … is not only the first mover of the cosmos, whereby the latter is left to its universal rules, but is an active force therein'.[551] This 'first and unknown Cause of Motion' bears a resemblance to the Stoic concept of tension (*tonos)*, which is inseparable from the plenum (*pneuma*) 'that constitutes creative life', to borrow from Thomas Rosenmeyer, and is an active primary motion 'in the sense that there is nothing that is not in a state of tension with other parts'.[552] Further, Steno mentions that 'the Pagans themselves believed there was something of [the] Divine' in this 'unknown' motion, which has the power to produce effects 'contrary to the usual course of Nature'.[553]

Anticipating retorts, Steno provides analogies designed to convince the reader that to deny God the power to produce effects 'repugnant to the ordinary Laws of Nature' is to 'deny Man the power of altering the Course of Rivers … of inoculating a twig of one Plant into the branch of another Plant; of bringing upon a Table the Fruits of Summer in the midst of Winter; of producing [ice] in the heats of Summer' and so on – that is, to deny man of '*Artificial*' motions.[554] According to Rosenmeyer, in *Senecan Drama and Stoic Cosmology,* Stoic teachers preferred simplicity in images when employing a succession of visual descriptions to explain topics on physics and ethics – textual images that were 'taken from the texture of everyday experience,' such as Steno's descriptions of "summer fruits in winter" and "ice in summer" and so on – images that pile one upon another like Seneca's 'epic similes' or examples.[555] In Book 2 [originally Book 8]: *On Lightning and Thunder* of Seneca's *Natural Questions*, Seneca explains his repetition of the same thing

[551] Stefano Miniati, *Nicholas Steno's Challenge for Truth: Reconciling Science and Faith* (Milano, Italy: Franco Angeli, 2009), 275.
[552] Rosenmeyer, *Senecan Drama and Stoic Cosmology*, 103.
[553] Steno, *Prodromus,* 16.
[554] Steno, *Prodromus,* 16–17. Note that 'ice' is from the errata in Oldenburg's translation.
[555] Rosenmeyer, *Senecan Drama and Stoic Cosmology*, 45, 46.

with slightly varying examples thus: 'I am not going over the same point again for the sake of verbal gymnastics, but to prove that these things are related and of the same kind and nature'.[556] In the *Prodromus*, Steno admits that he is also applying his template for a common physics, taken from Seneca's advice on common morals, to choices of diction and syntax in philosophical discourse: '*Conformably to the same,* I give an account of the various ways of speaking, *commonly* received'. And here, at the end of his explanation of motion, Steno's use of simplicity serves to further drive home the belief that

> if we our selves, who [are ignorant of] both our Fabrick, and that of other Bodies, do daily change the Determination of Natural Motions; *why should not He be able to change the determination of the same, who doth not only know, but hath produced* our *frame, and that of all other Animals?*[557]

By mentioning that God '*hath produced* our *frame*', Steno also implicitly reminds the reader *how* 'our frame' was produced in the beginning: 'of the dust *of* the ground' (cited at the beginning of this chapter). But Steno argues that 'to admire in Artificial things the Wit of man acting freely, and yet to deny to things produced by Nature a Free Mover' would be a 'pretended subtilty', because

> Man, when hath made most Artificial things, *does not see but very darkly what he hath done,* nor what Instruments he hath used, nor what is that cause that moveth the Instruments.[558]

What Steno means is that we lack true knowledge of causes, even as creators of artificial objects, since our knowledge is always mediated: 'Man … does not see but very darkly what he hath done' (as put by Paul in the Corinthians, 'For now we see *through a glass darkly*; but then face to face: *now I know in part*; but then shall I know even as I am known').[559] What seems to be knowledge is ignorance, and like glass, where we are forced to look through a physical

[556] Seneca, *Natural Questions*, 21.1.4, 173. See also page 15 of the *Translator's Introduction* in the same work for Hine's explanation on Seneca's use of vivid imagery, slightly altered repetition, and other tropes.
[557] Steno, *Prodromus,* 17. Italics added.
[558] Steno, *Prodromus,* 17. Italics added.
[559] 1 *Corinthians* 13:12 (KJV). Italics added.

object and through our own dark reflection to see beyond, the 'Instruments' made by 'Man' only add more mediation between us and nature. This model of thinking springs from an Aristotelian tradition of knowledge, and is the antithesis of Hooke's radical instrumental empiricism where, like Galileo's telescope and his own microscope, artificial instruments are designed to replace inferior natural ones.[560] Yet Steno's 'Laws of an *Analysis*' are meant to minimise distortions created by all forms of mediation as much as possible 'in the Examination of Natural things'. Again, his inversion of the relation between Stoic physics and ethics creates a moral middle ground between 'Experiments and Reason' to establish 'Causes' agreed upon by all philosophers. The Stoic template with its emphasis on commonality, rather than the Scriptures, allows Steno to make the following sweeping claims:

> All these particulars I do at large discourse of, as demonstrated by both Experiments and Reason, to shew that … *what I have affirm'd of Matter, hath place every where … So also what I have proposed of the* Determination *of Motion, agreeth with every Mover,* whether … the Form, or the Idea, or the common Subtile matter, or the proper Subtile matter, or the particular Soul, or the Soul of the World, or the Immediate concourse of God.[561]

These hard generalisations serve as axioms for Steno's Earth studies. By coupling the Biblical account of the genesis of man *of* the earth, with his assumptions about matter and motion, using his Stoic template for a common, moral physics, composed by borrowing Stoic elements of style like simplicity over ostentation in natural-philosophical discourse, Steno completes his outline of a holistic-organic physics where the whole existed before the parts, and man is metaphysically part of the earth.

## 7.2 'Place'

[560] Gal and Chen-Morris, *Baroque Science*.
[561] Steno, *Prodromus,* 17–18. Italics added.

> What the *Earth* produceth, hath *nothing else* from the Earth, than the Place in which it is produced, and the matter ministered to it through the Pores of the Place.[562]

'Place' is the most important aspect of Steno's argument on the changing face of the earth, and '*Cockle-shells*' found out of place. The structure and dynamics of matter and motion in and of places can be studied comparatively to intimate 'how from that which is sensible, something certain may be concluded about that which is not sensible' – or, as mentioned, 'How the *Present* state of a thing may discover the *Former* state of the same'. This type of historical thinking is like Hooke's idea that one can "read" petrified bodies as nature's "documents" to enforce patterns of causality onto contingent past events. Again, the act of observing and experimenting upon these bodies, with particular places and times embedded in their physical makeup, provides a tangent historical experience – the past is present.

Yet 'Place' presents Steno with his greatest challenge when it comes to accounting for the origin of displaced bodies – 'Bodies, whose *place*, where they are found, hath made many doubt of the place of their production'.[563] 'Place' cannot serve as part of the framework of Steno's common physics because there is no consensus, but rather controversy, about it. Indeed, when Ray later pointed out that the *lapides sui generis* opinion is "modern", he was probably paraphrasing Steno who explains that 'The Ancients were exercised with one only difficulty, which was, How *Marine* Bodies came to be left in Places remote from the Sea', whereas the "modern" opinion or problem is to account for their origin: 'they have almost all busied themselves about the Origin of the said Bodies'.[564] For example, the *lapides sui generis* assumption is that fossils are found in place, so accounting for their origin, that is, how and why they are generated in stone, gains importance over accounting for how they were dislocated from their place of origin. Although Steno neglects to add that the historical change has roots in the literal interpretation of the Scriptures with

562 Steno, *Prodromus,* 19–20. Italics added.
563 Steno, *Prodromus,* 96.
564 Steno, *Prodromus,* 10–11.

physico-theological (in the sense explained previously) implications, possibly because it is self-evident, he, like Hooke, sides with the ancients that the most important part of the fossils puzzle is motion. Moreover, in general terms, Steno argues that 'whatever contributeth any thing to the production of a Body, *that* [thing] acts either as a *Place*, or as *Matter*, or a *Mover*: hence when like produceth like, it giveth it both Place and Matter, and the Motion of Production'.[565] But matter's fundamentals are 'occult' or unknowable; and although 'Things produced by Nature have the motion of their Particles from the motion of some penetrating Fluid, whether from the Sun, or from Fire contained in some terrestrial matter, or from any other cause unknown to Us … who ever shall duly weigh the Answers of all these, will find nothing but what's occult,' because nature (ascribing 'the production of all things' to nature is too broad a description), sun-beams and so on 'are nothing else but *Names*'.[566]

In an attempt to avoid the difficulties associated with 'Place' above, Steno defines 'the word *Place*' as 'that Matter, which by its superficie immediately toucheth the superficie of that Body, which is said to be in that *Place*'.[567] Thus, like Descartes's definition of 'external place', place for Steno is an absolute location or position (though he sometimes uses the descriptive definition): place is relative to a specific body under scrutiny, such as a fossilised marine creature. In his *Principles*, Descartes provides an analogy of a boat moving upstream while simultaneously being pushed downstream with equal power by wind, and explains that the boat's 'situation with respect to the banks is not changed' even though the stream courses around the boat in one direction while the wind blows around it in another, and so 'it remains in the same place, although the whole superficies around it is incessantly changing'.[568] But Steno is interested in the opposite situation, and unlike Descartes, for whom place is 'nothing more than a mode', place for Steno is the surrounding matter in immediate contact with a specific body's

565 Steno, *Prodromus,* 18.
566 Steno, *Prodromus,* 20.
567 Steno, *Prodromus,* 24.
568 René Descartes, and Valentine Rodger Miller, and Reese P Miller (trans and eds), *Principles of Philosophy* (Dordrecht: Kluwer Academic Publishers, 1982), II.15.

boundaries, or its superficies.[569] This is an important distinction because Steno does not only need to show that a body is out of place; he also needs to account for its place of origin; and since the 'Matter' of a place allows for 'various differences' of places and bodies, the physical effects caused by these differences contrast when a body is out of place and correspond when it is in place – the latter allowing for the identification of a body's origin.

First, the state of matter of a place is 'either all solid, or all fluid, or partly the one and partly the other'; secondly, it is 'all sensible by it self, or in part so, and in part by its operations' or physical processes; 'Thirdly, 'Tis either altogether contiguous to the Body contain'd, or in part continuous to the same', causing variety.[570] Finally, to prevent painting places and bodies as static things, the matter of a place, according to Steno, is 'either always the same, or by little and little changed':[571] 'So the Place, wherein a Plant grows, is all that matter, which by its superficie immediately toucheth the whole superficie of the Plant', but also the matter 'included in the seed of a Plant', which it

> had from another Plant *both* the Matter *wherein* 'tis produced *and* the Matter *out of which* 'tis produced, *and* the Motion of the Particles by which 'tis formed.[572]

'So the place, where from a fallen blossom grows an Orange, is partly the little *pedunculus* or stalk continuous with it, partly the contiguous Air'.[573] It is likewise for 'Animals included in the Egg of the like Animals' – and here Steno sides with the popular ovum theory of generation that Ray later defended, as discussed in the last chapter – which compound the matter in the egg with the matter of their place. That is, 'the Place, where an Animal first begins to grow'.[574] Thus, a

569 Descartes, *Principles of Philosophy*, II.15: 'external place may be taken as being the superficies that immediately surrounds the thing placed. It ought to be remarked that by superficies we do not here understand any part of the surrounding body, but only the boundary between the surrounding and surrounded bodies, which is nothing more than a mode …'
570 Steno, *Prodromus,* 24–25.
571 Steno, *Prodromus,* 25.
572 Steno, *Prodromus,* 19, 25.
573 Steno, *Prodromus,* 19, 25.
574 Steno, *Prodromus,* 19, 25.

body in a place is always contained by the matter of its place, even when the place is 'by little and little changed' – 'sometimes made up of Earth and Air, sometimes of Earth and Water,' and so on.[575] These four explanations about how 'Matter admits of various differences' in a place serve to clarify 'the ambiguous sence of the word Place' so that Steno's use of it 'may not beget new doubts' in the middle of his 'three Propositions' on 'a *Solid contain'd within a Solid*'.[576]

Steno's three propositions are in answer to the general '*Question proposed*': 'Whether Bodies like to Marine Bodies, found at a great distance from the Sea, had been anciently produced in the Sea?'[577] That is, whether marine fossils are out of place. In this respect, Steno's first proposition[578] concerning solid bodies enclosed in solids, and which 'of the two was first hardned', states that the imprints of fossil bodies on the surrounding places where they are dug up show that 'the Matter of the Earths and Stones containing them was yet fluid'. Consequently, observations of fossil traces stamped into rock like wax seals provide visual evidence that 'Bodies like to Marine Bodies' were made before the earthly matter in which they are found, or 'that those Earths or Stones are so far from having produced the Bodies contain'd in them, that they were not there existent, when those Bodies were produced'.[579] Never one to neglect the contrary conundrum, Steno considers 'Veins of Minerals, which fill up the fissures of the Stones' and so on. In such a situation, he observes that 'the Bodies containing were then already hard, when the matter of the Bodies contain'd was yet fluid'.[580] Further, Steno's second proposition, where he gives his definition of place, serves to underscore the notion that all kinds of bodies are out of place by considering not only visible surface appearances but also sensible and insensible internal

[575] Steno, *Prodromus,* 19, 25.
[576] Steno, *Prodromus,* 24, 22, 34.
[577] Steno, *Prodromus,* 24, 22, 12.
[578] Steno, *Prodromus*, 22: 'If a Solid Body be every where encompass'd by another Solid Body, that of the two was first hardned, which in the mutual contact doth express on its superficie the proprieties of the superficie of the other".
[579] Steno, *Prodromus,* 22.
[580] Steno, *Prodromus,* 23.

composition and structure.

> If a Solid Body be every where like another Solid, not only as to surface, but also in the inner constitution and frame of its parts and particles, then it will also be like it as to the Manner and Place of its production …[581]

For Steno, just as for Hooke, it is an important ontological-methodological law that if a stone shell dug out of the earth resembles a marine creature, not only externally but also internally, then it is of the sea not of the earth. This applies not only to fossils but all matter. For example, sediments are out of place: 'the *Beds* of the Earth, for the place and manner of their production, agree with those Beds, *which turbid Waters let fall*'.[582]

Finally, the first two propositions depend on the reader accepting Steno's third proposition – the Stoic-like notion of a subtle fluid that pervades all bodies: '*If a Body be produced according to the Laws of Nature, it is produced out of a Fluid*'. Steno supports this last claim uniquely with his background knowledge as an anatomist, comparing the compartmentalised fluids of the human body with the earth's. Thus, like Hooke again, who recall asks scornfully why nature never produces stone roses ('Why do we not dig out of Mines ever-lasting Vegetables, as Grass for instance, or Roses … Were it not that the Shells of Fishes are made of a kind of stony Substance which is not apt to corrupt and decay'[583]), Steno argues against the *lapides sui generis* opinion of a plastic virtue in the earth, and the ad hoc *lusus naturae* explanation, stating that 'if we give to the Earth a power to produce these Bodies', fossils such as those 'like to Marine Bodies', then 'we cannot take from her the faculty of producing others'.

That there are limited kinds of fossilised bodies becomes an important part of Steno's argument. The *lapides sui generis* plastic virtue would have to be in particular places in the earth, since not every place produces 'Marine Bodies', and again, if 'one shall say that they are produced by the power of

[581] Steno, *Prodromus,* 23.
[582] Steno, *Prodromus,* 23–24. Italics added.
[583] Hooke, *Discourse of Earthquakes*, 318.

the place, he will be necessitated to acknowledge all others to be produced by the same power'. To demonstrate that this is *not* how things are, Steno needs to '*examine Every Solid naturally included in a Solid'*, to support not only that marine fossils are out of place, but also that other parts of the earth have been dislocated too over time. Accordingly, one must 'consider the nature *both* of the place where [a solid] is found, *and* of the place where it is produced'.[584]

> But no Man will easily determine the *Place* of Production, who knows not the *Manner* of the Production, and discoursing of the manner of Production will be to no purpose, if a certain knowledge be not had of the *Nature* of *Matter*.[585]

Moreover, just as for nature, ascribing 'the production of all things' to the earth is too broad a description as well.[586]

> He that shall ascribe the production of a thing to the *Earth*, nameth, 'tis true, a *Place*; but since to all terrestrial things the Earth affords *place* (at least in part) … the place alone is not sufficient to produce a Body.[587]

Yet, as Oldenburg mentions in the preface, Hooke highlights in *Lampas*, and Ray points out more than once, Steno's propositions are not novel; recall that Hooke discusses all three in the *Micrographia* and his *Discourse* presentations and lectures. It is possible that historians have paid more attention to Steno over Hooke in the past because, paradoxically, Hooke's Royal Society style of discourse sometimes buries information in an overabundance of details. Nevertheless, although Steno's work is like Hooke's, Steno harbours different motivations, doubts and anxieties that the final products, that is, his propositions, wrap up and hide from view. Moreover, the idiosyncrasies of his method versus Hooke's reveal important new ways that natural philosophers reach the same conclusions, and thus attempt to produce and establish the same matters of fact, albeit from different cultural

[584] Steno, *Prodromus,* 12–13.
[585] Steno, *Prodromus,* 13.
[586] Steno, *Prodromus,* 20–21.
[587] Steno, *Prodromus,* 21.

and intellectual traditions.[588] Examining Steno's anatomical approach to the study of the earth, especially fluids as producers and transporters of solids, brings to the fore the ontological and epistemological difficulties he encounters when attempting to convince his readers that fossils are of organic origin, and that the earth's 'Face' has changed dramatically over time. Indeed, according to Steno, the earth has had six faces throughout history.

### 7.3 'Fluid'

Steno's tools and techniques, as has been noted, stem from his studies of human anatomy and physiology.[589] While studying medicine at Leiden, Steno distanced himself from Descartes, nevertheless continuing to agree with the 'manner' in which 'Monsieur *Des Cartes* also explains the production of the Beds of the Earth'; and although in his earlier 1667 work on the dissection of a shark's head, Steno praised Pierre Gassendi's ideas on signs and correspondences between the microcosm and the macrocosm when discussing the formation of stones in the human body, he rejects appeals to correspondences in the *Prodromus* two years later, also criticising Athanasius Kircher's reliance on this explanatory device.[590] So here we have another, albeit small, example of a change occurring to the alchemical world picture, with respect to the earth as a living body: not an abandonment of alchemy

[588] For a comprehensive account of the importance of experiments in establishing matters of fact, and the cultural, social and personal difficulties involved, see David Gooding, Trevor Pinch and Simon Schaffer (eds), *The uses of experiment* (Cambridge: Cambridge University Press, 1989).

[589] Kardel and Maquet (eds), *Nicolaus Steno*.

[590] Steno, *Prodromus*, 39. Nicolaus Steno, *Canis Carchariae dissectum caput*, 102–103, in *Nicolai Stenosis Elementorum myologiae specimen* … (Florence: Ex typographia sub signo stellae, 1667): 'Quod Diaetae diuersitas in microcosmi humoribus efficit, idem Solis, & Lunae vicissitudines, variaeque mutations aliae in terrae humoribus poterint producer. Manifestissimo exemplo idem confirmat Galliae lumen Gassendus; dum lapidum productionem in philosophia sua explicat' (transcribed by me). According to Oldroyd, for mediaeval and Renaissance alchemists working either in the Aristotelian, Platonic or Neoplatonic, or Stoic tradition, it was 'a common feature … to think of the earth as in some sense alive': Oldroyd, *Thinking about the Earth*, 29–30. Toshihiro Yamada, 'Kircher and Steno on the "geocosm"', in Gian Battista Vai and WGE Caldwell (eds), *The Origins of Geology in Italy*, Vol. 411 (Colorado: The Geological Society of America, 2006), 69, 73. For a radical re-interpretation of Kircher's hypotheses on fossils (in the sense of all things dug up), which rejects the interpretations of Kircher as understood by Hooke, Steno, Leibniz and so on, see Stephen Jay Gould, 'Father Athanasius on the Isthmus of a Middle State', 201–237. For opposition to Gould's re-interpretation of Kircher's stance on fossils, see Roger Ariew, 'Chapter 2, Leibniz and the Petrifying virtue of the Place'.

for chemistry, as is so often trumpeted in the literature, but a change in how alchemical ideas are thought about and practiced.

Owing to his assertion that the human body, like the earth, follows '*the Laws of Nature'*, producing solids '*out of a Fluid'*, Steno 'observe[s] at least *three* sorts of Fluids in Animals', which he can use to sensually complement his more abstract choice of the Stoic concept of *pneuma,* 'a Subtil fluid pervading all' with concrete bodily fluids that can be studied and compared with earthy ones such as groundwater.[591] The human body as a whole is revealed in layers, for example, by stripping away skin, fat and muscle to the viscera, and it contains compartmentalised fluids, such as blood in arteries and veins, and urine in the bladder. Steno translates and applies his anatomical skills to the earth's visible layers, textures, and fluids, with an approach that strips the whole down to its layers and parts, further underscoring his commitment to a holistic-organic worldview in which the earth is a living organism. Johannes Kepler and William Gilbert were both committed to similar concepts; the latter attempted to overthrow Aristotelian notions on the earth's humours and exhalations with a novel chemistry of iron. Gilbert's chemical ideas are often overshadowed by his work on magnetism, which Kepler adopted for some time to explain why and how planets move. But Gilbert's claims on the reactions of earthy matter did not go unnoticed by his contemporaries: for example, Lister, who recall stated that Steno's view of nature is different from his own, was a follower of Gilbert's chemistry of iron (though not uncritically), applying it to investigations of natural springs.[592] Further, as indicated by Toshihiro Yamada, around a decade before publishing the *Prodromus*, Steno noted down Gilbert's name while poring over Athanasius Kircher's *Magnes sive de arte magnetica* (1643 second edition) as a student, a work that was allegedly crafted to supersede Gilbert's *De Magnete* (1600).[593] Whether Steno

[591] Steno, *Prodromus*, 28–29.

[592] A M Duncan, *Introduction*, in Johannes Kepler, and E J Aiton, A M Duncan, and J V Field, *The Harmony of the World* (Philadelphia: The American Philosophical Society,1997), xiii. Roos, *Web of Nature*, 214–215.

[593] Yamada, 'Kircher and Steno on the "geocosm"', 72–73. Yamada argues that Steno owes a heftier intellectual debt to Kircher than Descartes [which makes sense given Steno's belief that the earth is an organism], and that through Kircher there is also a relation between Steno and

took a leaf directly out of the same resource used by Kepler and Lister, or studied Gilbert via Kircher, he likens crystal growth to magnetic attraction, and his concept of the interaction of place and solid is comparable to Gilbert's reformulation of Aristotle's concept of 'exhalations' in the genesis of metals and other earthy bodies from fluids.[594] As discussed previously, Steno thinks about an earthy solid and its place of origin in terms of interactivity or reactivity, which apart from allowing him to make comparisons of place also gives him a way to account for change and variety. Unlike Gilbert, however, he refuses to discuss insensibles, that is, physical processes in the production of a solid that are occluded from the senses – in this case, how a solid acquires its natural form: 'I candidly acknowledge that the first *Delineation* of them [solids] is not only doubtful but quite unknown to me'.[595] Nevertheless, in his discourse on 'the production of a Solid Body' in and from a fluid, Steno, like Hooke and Gilbert, draws attention to a Copernican shift of the mind – the idea that the earth undergoes invisible, insensible motions through time.

## 7.3.1 Gilbert

Similarly to Steno, Gilbert's interest in the earth grew from studying the human body. Physician to Elizabeth I for a couple of years, and more notably a radical early experimentalist who at the turn of the seventeenth century published *De Magnete*, the first comprehensive treatise on his 'magnetical philosophy', Gilbert applied a differential diagnosis to his more passionate interest – iron. In Chapter 7 (Book I) on 'What iron is. What its Matter, its use', Gilbert analogises the human body to explain the workings of the earth. After dismissing all previous work on the subject, as well as differing claims on the 'prime elements', Gilbert gives his novel 'opinion' on earthy bodies. In contrast to Aristotle who 'supposed their matter to be an exhalation', and chemists who 'declare that sulphur and quicksilver are the prime elements', as well as Gilgil

Pierre Gassendi with respect to earth studies and fossils.

594 Steno, *Prodromus*, 60–61.

595 Steno, *Prodromus*, 26.

of Sevilla, Agricola and others, Gilbert claims that

> [M]etals have their origin and do effloresce in the uppermost parts of the globe, each distinct by its form, as do many other minerals and all the bodies around us.[596]

By 'effloresce' he does not mean "blowing upwards" and is not thinking of "effluvia" or particles of matter that waft from substances to give off scent;[597] rather, Gilbert's use of the verb 'effloresce' agrees with the current descriptive definition in that it represents the action of something moist condensing, dehydrating and hardening – in this particular instance an earthy humour as it moves up from 'the bowels of the earth' through 'veins' to the superficies.

> The humors come from sublimed vapors that have their origin in the bowels of the earth. And all waters are extractions from the earth and exudations, as it were. Therefore Aristotle is partly right when he says that the exhalation which condenses in the earth's veins is the prime matter of metals[.][598]

For Gilbert, this is no analogy: the earth *really* sweats and breathes; its exhalations are the 'prime matter' of metals and other earthy matter; and for Steno, too, 'Stones of divers nature, sweating out divers fluids', for example, 'produce Chrystals of different Colours'.[599]

Gilbert argues that water is not 'an element, but only a less complex consistence of the earth's evaporated fluids … Nor is the earth a simple substance, as the Peripatetics imagine' – although he allows for a 'true substance of the earth'. According to Gilbert, the 'bowels of the earth' are

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596 William Gilbert, and P Fleury Mottelay (trans), *Of the Loadstone and Magnetic Bodies, and on the Great Magnet the Earth* (London: Bernard Quaritch, 1893), 34. Italics added. (Henceforth *De Magnete*.)

597 Dyche, *A New General English Dictionary*, EGR.

598 Gilbert, *De Magnete*, 35. For Aristotle's definition of 'humid' or 'moist' (matter not bounded by itself), see Aristotle, *On Generation and Corruption*, in Aristotle, and Jonathan Barnes (ed), *The Complete Works of Aristotle, the Revised Oxford Translation, One Volume Digital Edition* (Princeton: Bollingen Series, Princeton University Press, 1995 [1984]), II.2, 1181. Interestingly, Kepler calls Aristotle's definition the 'geometrical definition': Johannes Kepler, and William H Donahue (trans), *Optics: Paralipomena to Witelo & the Optical Part of Astronomy*, (Santa Fe, New Mexico: Green Lion Press, 2000), 22.

599 Steno, *Prodromus*, 59. According to Oldroyd, for mediaeval and Renaissance alchemists working either in the Aristotelian, Platonic or Neoplatonic, or Stoic tradition, it was 'a common feature … to think of the earth as in some sense alive': Oldroyd, *Thinking about the Earth*, 29–30.

hot, and as vapours move up to the superficies through veins, they condense to humours. Thus, 'all waters are extractions from the earth and exudations, as it were'. These exudations 'condense [even more] in the earth's veins' and 'more temperate cavities' to a 'concreted matter'. Up to here, Gilbert's 'opinion' dogs Aristotle's, but then he veers off into a claim about how these exhalations are informed (in the Aristotelian sense): in the veins and cavities, which are 'moderately warm spaces', this 'prime matter' of various earthy bodies 'takes shape, *just as in the warm uterus the seed or embryo grows*'.[600] Recall, Steno rewords this with a plant analogy that he then likens to the development of 'Animals included in the Egg of the like Animals'. But here, Gilbert is attempting a rhetorical gymnastics that Steno principally ignores: to overturn not only Aristotle, who is only 'partly right' because his conjecture that 'the exhalation which condenses in the earth's veins is the prime matter of metals' fails to account for the variety of forms, but also mediaeval Aristotelian notions on the formation of earthy bodies as a whole. Since Steno's analysis of fossils places great onus on the relations between fluids and solids, it is worth examining his resources in more detail.

### 7.3.2 'AS THE PERIPATETICS IMAGINE'

Mediaeval alchemists attained some ideas from Aristotle's *Meteorologica,* modifying them into the sulphur-mercury (or sulphur-quicksilver) hypothesis, usually attributed to Jabir ibn Hayyan or Geber, which is the concept that metals are formed by a complex of sulphur and mercury exhalations in the earth.[601] In Book I of the *Meteorologica,* as an explanation for the cause of 'burning flames' and 'shooting-stars' in the sky, Aristotle begins his solution to the problem of how it is that warm exhalations arise from cold, dry earth.

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600 Gilbert, *De Magnete*, 35. Italics added.

601 Jennifer M Rampling, 'Theory Choice in Medieval Alchemy', in Emma Tobin and Chiara Ambrosio (eds), *Theory Choice in the History of Chemical Practices* (Switzerland: Springer, 2016), 9; J A Norris, 'The mineral exhalation theory of metallogenesis in pre-modern mineral science'. Ambix 53:43–65, 2006; Edgar Hill Duncan, 'The Natural History of Metals and Minerals in the Universe of Milton's Paradise Lost' (*Osiris*, Vol. 11 [1954], 386–421), 389, 392.

> When the sun warms the earth the evaporation which takes place is necessarily of two kinds, not of one as some think. One kind is rather of the nature of vapour, the other of the nature of windy exhalation. That which rises from the moisture contained in the earth and on its surface is vapour, while that rising from the earth itself, which is dry, is like smoke.[602]

Further, 'windy exhalation, being warm, rises above the moister vapour, which is heavy and sinks below the other', and later, in Book II, Aristotle attributes a second efficient cause to the levity of exhalations: 'a great quantity of fire and heat in the earth'.[603] Finally, in the close of Book III, he moves to the production of earthy bodies, and attempts to 'describe' the 'operations' of secretions when they are 'shut up in the parts of the earth' – sometimes causing earthquakes.[604] He maintains 'that there are two exhalations, one vaporous the other smoky,' adding that from these two 'there correspond two kinds of bodies that originate in the earth, "fossiles" and metals'. By 'fossiles', the original meaning of which is anything dug up from the earth, Aristotle means 'the kinds of stones that cannot be melted … and ruddle, and sulphur' and so on, the cause of which is the 'heat of the dry exhalation'.[605] In contrast, the 'vaporous exhalation is the cause of all metals … All these originate from the imprisonment of the vaporous exhalation in the earth, and especially in stones,' which 'compress' the exhalations with their 'dryness' so that

> it congeals just as dew or hor-frost does when it has been separated off, though in the present case the metals are generated before that segregation occurs. Hence, they are [the element of] water in a sense, and in a sense not.[606]

Aristotle's account of the formal causes for various metals and 'fossiles' from these congealed exhalations is vague, creating more questions than it answers; alchemists of the mediaeval sulphur-mercury tradition, which had three competing schools of thought (for example, Paracelsus, discussed

602 Aristotle, *Meteorologica*, Book I.4, 341b.
603 Aristotle, *Meteorologica*, Book II.3, 359b–360a.
604 Aristotle, *Meteorologica*, Book III. 6, 378a.
605 Aristotle, *Meteorologica*, Book III. 6, 378a.
606 Aristotle, *Meteorologica*, Book III. 6, 378a.

earlier, would add a third principle – salt), took up the challenge, fashioning the theoretical tool of sulphur-mercury to explain variety with different proportions of 'sulphur' and 'mercury' in varying degrees of purity. To sketch their modifications briefly, sulphur is a dry exhalation and mercury is a moist one; these two principles react to form products of the sulphur-mercury complex: rocks, ores, minerals and metals.[607]

### 7.3.3 Inversions

Although the sulphur-mercury complex was crafted to account for phenomena that Aristotle's physics could not explain – for example, the reversal of reactions such as dissolution and precipitation – according to Gilbert it is a lame explanatory device because the most ideal product of these "reactions" is gold owing to its rarity, perfection and therefore inertness or state of rest (the four elements perfectly combined and stable).[608]

Reeves argued that Gilbert's 'contempt for gold and ardour for iron' is an example of an inversion of values that had already appeared in the guise of a gold chamber-pot in Thomas More's *Utopia* (1516), but which was set in motion by Copernicus's *De revolutionibus* ... For Gilbert, gold symbolises the Aristotelian norms associated with a static earth and unchanging heavens; his interest is in abundant and reactive metals like iron, which have greater utility, and complement his dynamic, semi-Copernican worldview.[609] A few years later, Kepler's *Astronomia Nova* would physicalise astronomy by propelling real material bodies and their motions up into the heavens, the traditional realm of

[607] Rampling, 'Theory Choice in Medieval Alchemy', 9. J A Norris, 'The mineral exhalation theory of metallogenesis in pre-modern mineral science'. Ambix 53:43–65, 1989; Edgar Hill Duncan, 'The Natural History of Metals and Minerals in the Universe of Milton's *Paradise Lost*', (*Osiris*, Vol. 11, 1954, pp. 386–421). For Paracelsus, see Oldroyd, *Thinking about the Earth*, 29–30, 32: according to Oldroyd, Paracelsus thought of the earth as a living being, with wombs or matrices where seeds ('which can be traced back to the Stoic doctrine of the *logoi spermatikoi* or "seminal reasons"') gestate into minerals. Unlike Gilbert, Paracelsus attributes this to 'matrix water'. But it is regrettably beyond the scope of this subsection to go into greater detail on the many alchemists who attempted to answer questions concerning metals and minerals.

[608] Jennifer M Rampling, 'Theory Choice in Medieval Alchemy'. Gilbert, *De Magnete*, Book I.

[609] Reeves, 'As Good as Gold: The Mobile Earth and Early Modern Economics', 154.

rest. Later still, in his epic poem *Paradise Lost* (1667), John Milton, who was well-versed in the sulphur-mercury hypothesis and alchemy, tropes the inversion by placing mines and forges not only in the bowels of the earth or hell, but also in heaven.[610]

In Chapter 3, we discussed a similar inversion of values, that is, a growing interest in the earth's materiality over the unchanging and divine, with Hooke's use of gold as an analogical argument for his experiments and findings on fossils, his promotion of simplicity over ostentation in experimental and instrumental design, and his treatment of fossils as valuable and serious objects of intellectual currency instead of "clay" products of nature's games. As Catherine Wilson has pointed out, Hooke's drawings in the *Micrographia*, and genre paintings like Vermeer's, which both deliberately draw attention to the beauty of the mundane, also exhibit this change in values.[611] We also returned to this change in Chapter 6, albeit from a different perspective, with an analysis of Hooke's inversion of the themes of ruin and decay, and the replacement of unchangeability with cyclical flux.

Gilbert attempts a shift from gold to iron; the preoccupation of inertness-as-ideal to reactivity; and in doing so explains diversity not with principles and proportions, but as the difference between matter that is 'homogeneous throughout' versus matter that is heterogeneous with 'other exhalations … mixed with foreign earths'.[612] Although Gilbert's configuration sounds similar to notions on elemental purity in the sulphur-mercury schools of thought, his heterogeneous mixtures are not the result of 'any *quantitas* or proportion of

[610] John Milton, in John Milton, and Philip Pullman, *Paradise Lost: an illustrated edition with an introduction by Philip Pullman* (Oxford: Oxford University Press, 2005 [1667]); Duncan, 'The Natural History of Metals and Minerals in the Universe of Milton's *Paradise Lost*', 387–388, 390, 407–409. Really, one ought to just read the whole paper. It's a fascinating read. For a sketch of changes to the alchemical mode of thought as reflected in poetry, (for example, the language of Donne versus the language of Milton), see Cindy Hodoba Eric, 'The Flesh Made Word: a word on seventeenth-century "true names" as an epistemology of sensibility', *Academia Letters*, Article 5536, June 2022, 2.

[611] Catherine Wilson 'Aesthetic Appreciation of Nature in Science', in Alina Payne (ed), *Vision and its Instruments: Art, Science, and Technology in Early Modern Europe* (University Park, Pennsylvania, USA: The Pennsylvania State University Press, 2015), 49–58. See also Hodoba Eric, *The Capture of Spring*, 66.

[612] Gilbert, *De Magnete*, 35.

matter *nor by any specific virtues of matter*, as the chemists fondly imagine'; rather, variety is the result of *place* – just as it is for Steno later – because different substances must be in physical contact to react.[613]

### 7.3.4 'Solid'

Similarly, Gilbert's 'prime matter' can only be *informed* by the surrounding 'earth cavities and the conformation of the ground concurring *with the fit matter*'. For example, 'in mines' the earth's 'efflorescences'

> ascend in great volume, with double the humor from the exhalations; in the subterranean spaces they are consolidated into metallic ores; so too they are produced together, *and in virtue of their place and of the surrounding bodies, they acquire, in natural matrices, their specific forms*.[614]

After taking time to dismiss 'simpletons and raving astrologers' who 'refer to the several planets their respective metals', that is, upon rejecting the microcosm-macrocosm worldview where entities in the celestial realm influence terrestrial ones and vice versa, Gilbert concludes that 'exhalations are the remote cause of the generation of metals; the proximate cause is the fluid from the exhalations: *like the blood and semen in the generations of animals*'. The simile is an idea that Gilbert borrows from Aristotle's *On the Generation of Animals*.[615] He attributes petrifactions offhandedly to 'exhalations and the fluids produced from them', which 'enter bodies often and change them'.[616] Referring to petrified wood parenthetically, Gilbert mentions that 'we may find instances of timber so transformed':

> But these exhalations and the fluids produced from them enter bodies often and change them into marchasites and they pass into veins (*we may find*

613 Gilbert, *De Magnete*, 36. According to Oldroyd, Albertus Magnus had slightly similar notions on the importance of place for variety in minerals, which he attempted to explain by translating Aristotle's notions on animal generation and digestion to the mineral kingdom: Oldroyd, *Thinking about the Earth*, 32.

614 Gilbert, *De Magnete*, 38. Italics added.

615 Gilbert, *De Magnete*, 36; Aristotle, *On the Generation of Animals*, Book I, in Aristotle, and Jonathan Barnes (ed), *The Complete Works of Aristotle*, 2426–2429.

616 Gilbert, *De Magnete*, 37.

> *instances of timber so transformed*), intro appropriate matrices within bodies, and these metals are formed[.][617]

Recall that Steno refuses to hypothesise on the cause of a solid's form or '*first Delineation*', for this is an operation that occurs occultly or insensibly and 'is unknown to us', although in accordance with his common physics, he remarks that 'according to that knowledge of matter', it 'can be nothing else but a Porous surface of that Solid [in its particular place], and a subtile Fluid permeating those pores'.[618] Steno is, however, willing to explicate the growth or '*Increase*' of a solid from sensible parts starting in fluid, but to do so, he needs to reformulate fluids.

Now, Steno allows for three general 'sorts of Fluids in Animals' and thus the earth: '*External*', '*Internal* and *Common*', and '*Internal* and *Appropriate* to each part'.[619] He is critical of natural philosophers who take into consideration only the common internal fluid, which is 'distributed towards all the parts of the Body' via, for example, the circulatory system; these philosophers 'ascribe all [production of solids] to the percolation through divers Pores', yet the production of a solid 'depends not from the Blood, but from the Places themselves' (according to his second proposition).[620] The blood, in Steno's conception, serves as a transporter 'for the distribution of warmth and food … but there are every where cavities, into which the parts sever'd from the blood are mixed with the Fluid of that [new] place' to where the food or warmth is transported 'to be added to the solid parts'.[621] And Steno stresses again that

> Although I am not able to determine, why in divers places from the same blood are discharged different Fluids … 'tis certain, that that depends not from the Blood, *but from the Places themselves*[.][622]

Just as food or warmth in the blood can be transported and added to a solid part of a different place in the body, 'Particles' from that place can also

[617] Gilbert, *De Magnete*, 36–37. Italics added.
[618] Steno, *Prodromus*, 26, 32.
[619] Steno, *Prodromus*, 28.
[620] Steno, *Prodromus*, 31–32, 23.
[621] Steno, *Prodromus*, 30
[622] Steno, *Prodromus*, 31. Italics added.

be 'worn off from the solid parts [to] fall back again into those hollownesses, to be again restored to the blood, and thereby conveyed away to the external Fluid'. The external fluid is most important for Steno's ideas on how a 'Body increaseth by an Apposition of new Particles severed from an External Fluid', or how every solid increases from a fluid, such as the formation of 'Stony and Chrystallin Shells, Metallick Plants, and many such like Bodies,' because he observes that it is where 'the Worms and Stones [are] generated within our Body,' and is thus where they are generated in the body of the earth.[623] The difference between the external fluid and internal ones is that it 'communicateth with the ambient fluid by channels without any intermediate capillary Vessels, that is, without percolation or straining'.[624] For example, the 'Wind pipe, which the Air inspired toucheth' and the bladder are places of external fluid in the human body; translating this knowledge to the body of the earth, the external fluid is

> not only that, which encompasseth the visible surface like an Atmosphere, but also that, which toucheth all the other surfaces of the Body that by the greater holes are continued to the said surface.[625]

For this reason, external fluids are capable of 'filling up the places of Bodies consumed' – such as the cavities in rotting sea creatures undergoing petrifaction. Steno concludes that external fluids likewise carry particles of solids into internal fluids via pores ('Percolation' and 'cribration'). As in the human body, both the place from and the place to where particles are transported determine whether a solid formed within a solid will become '*Sediments*, such as the Beds of the Earth … *Ramifications*, as those figures of Plants, which are seen in the crevices of stones … *Angular Bodies*, as Rock-Chrystal … *Repletions*, as all sorts of … Shells, Metallick Plants' and so on.[626] Owing to its versatility, Steno's fluid concept is a powerful tool that he applies to the formation of all solids as well as their dislocation, transportation and

623 Steno, *Prodromus*, 26, 33, 29.
624 Steno, *Prodromus*, 29.
625 Steno, *Prodromus*, 28.
626 Steno, *Prodromus*, 33.

location; and his compartmentalisation of various fluids in place and time prevents circularity in his argument that the '*Beds* of the Earth … are Solids naturally inclosed in Solids, *and* that in them are contained almost all those Bodies, which give occasion to the Question in hand [on fossils]'.[627] For a more particular example, Steno can claim that 'To the Sediments of Fluids do belong the *Strata* or *Beds* of the *Earth*', and also that terrestrial 'torrents' dislocate various solids such as '*Agats*' from their place, 'because by the rupture of the Beds the matter of the place hath been thrown here and there'.[628] More radically,

> If in any Bed there be found the fragments of another Bed, or the parts of Animals or Plants, 'tis certain, that such Beds are not to be reckoned among those, which in the Creation did subside from the first Fluid.[629]

[627] Steno, *Prodromus*, 52.
[628] Steno, *Prodromus*, 36.
[629] Steno, *Prodromus*, 38.

# CHAPTER 8: THE 'HISTORY OF CHANGES'

Steno claims that the earth's surface underwent significant natural changes *after* the 'Beds' that 'did subside from the first Fluid' during 'the Creation'; further, that 'we may distinguish *Six* distinct' faces of the earth, from Creation to the seventeenth century; and finally, that the earth has been 'twice Fluid, twice Plane and Dry, and twice Scabrous and Craggy'.[630] He is aware that *this* is his *Prodromus*'s most polemical claim, as well as being his answer to why marine bodies are found where they ought not to be. By weaving '*Nature* with *Scripture*', a technique of interpretation that Rossi called a "defence mechanism",[631] – in this case because it is designed to defend the authority of the Scriptures by giving them the last word on historical events – Steno attempts both to soften the blow and to guard against the possible danger of a subversion of tradition that his fossils might potentially cause.

> But least [sic] there should be apprehended any danger in the novelty, I shall in short lay down the agreement of *Nature* with *Scripture*, reciting withal the chief difficulties, that may be raised about each Face of the Earth.[632]

Although Steno mentions that seismic and volcanic activities alter landforms, he favours diluvial action, and announces himself a proponent of 'the Universal Deluge' explanatory device – a favourite amongst advocates of the organic origin of fossils – for how fragments of foreign strata, and petrified parts of animals and plants, end up embedded elsewhere.

Coupling his concept of fluids with Noah's flood, Steno describes and explains each face of the earth by supporting his most radical claims, similarly to Hooke, with analyses of natural, civil and sacred histories. Indeed, the *Prodromus* ends on a historical note, with a promise to expound upon the

630 Steno, *Prodromus*, 89, 98–99.
631 Rossi, *The Dark Abyss of Time*, xiv.
632 Steno, *Prodromus*, 99.

history of Italy in the abandoned *Dissertation*.[633] However, even though both Hooke and Steno craft concepts of fluids with respect to the formation of solids, and fossils in particular, providing new natural histories that complement novel ways to know and manipulate nature, examining how Steno reaches the same outcomes, by analysing not only his natural philosophy but also his hermeneutical strategies when selecting historical evidence, discloses that the two agree on the origin of fossils and the physical processes of their formation, but disagree on natural history because of divergent historical imaginations and thinking.

Hooke, in the *Micrographia* and his first *Discourse* lecture, argues that all bodies solidify from fluids, and that hard bodies were once soft, but he has little patience for the flood line of reasoning adopted by Steno, pointing out that the duration of the deluge was not long enough to sustain the causation of such changes, even as he himself was forced to fold his concept of fossil formation into a Biblical timescale, fabricating new historicities and finding himself meddled with new contradictions.[634] Indeed, on the organic origins side, Hooke was alone in his rejection of the deluge.[635] In contrast, Steno argues that ''tis evident, that in 4000 Years there have happen'd many and various Mutations', and even with Noah's deluge woven into his notions on fluids and natural history, Steno's concept of strata and fossil formation challenges ahistorical frameworks of continuity – such as those examined earlier with the work of Lister, and Plot in particular.

A third approach to the relations between these histories is provided by Kircher, whose intellectual ties to Steno were noted earlier. Kircher claimed that God had deliberately placed mountains onto an orthogonal grid to protect the earth's structure from change during the deluge.[636] As Nicoletta Morello

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633 Steno, *Prodromus*, 109.

634 For Hooke discussing the formation of solids in and from fluids, see, for example, Hooke, *Discourse*, 292–294. For censorship of Hooke by the Royal Society, see Birch, *The History of the Royal Society of London,* Vol. 1, 463; also see the Hooke Folio: CELL/RS/HF_010 © *Centre for Editing Lives and Letters*.

635 Tan Drake, *Restless Genius*, 28.

636 Nicoletta Morello, 'Steno, the fossils, the rocks, and the calendar of the Earth', in Gian Battista Vai and W Glen, and E Caldwell (eds), *The Origins of Geology in Italy* (Place unknown:

argued, both Descartes and Kircher did not incorporate a natural-historical account of the earth into their metaphysics. The former could not because the '*horror vacui*' was 'conceived outside of an historical dimension and a progression of the Earth'; that is, it was based on an interpretation of nature that considered space and structure, but not how a natural object is produced in time. The latter could not, according to Morello, because Jesuit explanations of the earth's formation allowed for 'no alteration and therefore no space for the history of Earth'.[637] This is a similar point to the one I argued earlier when discussing Ray's need to justify mountains. There, I mentioned the Jesuits of Coimbre, who did not want to incorporate natural history into their metaphysics, explaining instead that God made mountains because of their beauty and utility, and I examined Ray's appropriation of this idea. Kircher aptly makes this Jesuit move when claiming that mountains held the earth's original structure together during the deluge, for their ad hoc utility then was to protect the perfection of the first Creation. Conversely, Steno argues that the location of mountains is incidental and that the deluge altered the earth's topography, by using his concept of fluids and his Tuscan field studies of sedimentation and strata as a means to inject a monumental transformation into a static system.

Against this background of multiple experiences of nature, a juxtaposition of the differences in Hooke's and Steno's use of fossils as methodological tools of history, also the epistemological difficulties encountered in their ontology of fossils as non-mimetic objects, illuminates the mutating lines of thought about Earth's history. It is not their intertwining fossils hypothesis, but their differing historical practices and accounts, designed to support different and even opposing research ends, which shape and limit what emerges from their examinations of fossils in particular and the earth in general.

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Geological Society of America, Volume 411, 2006*)*, 89–90.

[637] Morello, 'Steno, the fossils, the rocks, and the calendar of the Earth', 87, 89. See also Rossi, *The Dark Abyss of Time*, 17–18.

## 8.1 'WHAT HAS HAPPENED'

Yet, as several scholars have argued, the early modern conception of historical truth and function, with roots in Aristotle's *Poetics*, was not set in stone, so it is worth taking a moment to sketch it.[638] Aristotle defines history as relating 'what has happened' and poetry as relating 'what may happen – what is possible according to the law of probability and necessity'.[639] He advocates the use of a unified historiographical framework or narrative structure, submitting parts to the whole: even a genuine historical fact should be omitted if it causes discontinuity in the narrative.[640] In this formulation, historians are redactors of *re*-presentations whereas poets are mimetic agents of creation. Thus, if a

> poet or 'maker' … chances to take a historical subject, he is none the less a poet; for there is no reason why some events that have actually happened should not conform to the law of the probable and possible, and in virtue of that quality in them he is their poet or maker.[641]

Because of this fundamental distinction between the roles of historians and poets, Aristotle concludes that 'poetry is a more philosophical and a higher thing than history: for poetry tends to express the universal, history the particular'.[642] Indeed, in the twelfth century, John of Salisbury, in his famous defence of the trivium, *The Metalogicon*, would state this an axiom – an axiom that would not be called into question until the poetry versus history controversy at the close of the sixteenth century, as we shall momentarily see.[643]

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638 Donald R Kelley and David Harris Sacks (eds), *The Historical Imagination in Early Modern Britain*. For alternative interpretations of verisimilitude in the *Poetics*, as well as early modern interpretations of Aristotle's distinction between poetry and history, see Paola Pugliatti, *Shakespeare the Historian* (New York, USA: Saint Martin's Press, 1996); Angus Vine, *In Defiance of Time: Antiquarian Writing in Early Modern England* (Oxford: Oxford University Press, 2010), 13–16.

639 Aristotle and S H Butcher (trans), *Poetics* (London: Macmillan, 1907 [250 BCE], MIT Internet Classics Archive edition), Section I, Part IX.

640 Aristotle, *Poetics,* Section I, Part VIII.

641 Aristotle, *Poetics*, Section I, Part IX.

642 Aristotle, *Poetics*, Section I, Part IX.

643 John of Salisbury, and Daniel D McGarry (trans and ed), *The Metalogicon* (Philadelphia: Paul Dry Books, 2009), 63. For primary sources on opposing sides of the controversy, see Philip Sidney, *The Defence of Poesy*, in Charles W Eliot (ed), *The Harvard Classics: English Essays, from Sir Philip*

The role of the poet in the above conception, as has been noted by the literature, is the antithesis of the seventeenth century commonplace of the primacy of reason and truth over imagination, commonly attributed to Francis Bacon (Chapter 2), whose work was studied by not only Hooke but also Steno.[644] Another interesting difference between Aristotle and Bacon is the latter's introduction of time-as-evidence into previously non-temporal or descriptive history, and the problems that this creates for representations of causality with narrative structure. As suggested before, time is an important factor in the discussion of apparently static fossils, which are paradoxically, as Hooke argues, a synecdoche of nature's diversity and dynamics, of natural changes occurring in time – from which a new knowledge system can be built. In *The Advancement of Learning* (1605), Bacon clearly considers Aristotle's definitions too broad for the task of treating history as evidence from which knowledge and "axioms" can be extracted. He divides knowledge traditionally into three parts:

> The *parts* of human learning have reference to the three parts of man's understanding, which is the seat of learning: *history* to his *memory*, *poesy* to his *imagination*, and *philosophy* to his *reason*.[645]

Partitioning '*history*' into four parts, '*natural*, *civil*, *ecclesiastical*, and *literary*', Bacon further subdivides each into three subcategories further segmented.[646] In these categories within categories, history is not 'what has happened', but the collection of memorable knowledge for the utility and improvement of the

*Sidney to Macaulay* (New York: P F Collier & Son, 1909–1914), at https://www.bartleby.com/27/1.html, re-accessed 22/12/22; and Samuel Daniel, The *ciuile wars betweene the howses of Lancaster and Yorke corrected and continued by Samuel Daniel …* (London: Simone Watersonne, 1609, Early English Books Online Text Creation Partnership, http://name.umdl.umich.edu/A19821.0001.001, re-accessed 22/12/22), I.6: 'And MEMORIE, preserv'resse of things done … / How causes, counsels, and euents did runne, / So long as these vnhappie times did last, / [Intermixt?] with fictions, fantasies. / *I versifie the troth; not Poetize*.' (Italics added.)

644 Kelley and Harris Sacks (eds), *The Historical Imagination in Early Modern Britain*, 4, 10. In his studies of Bacon, Steno references him as 'Verulam': Nicolaus Steno, and August Ziggelaar (ed), *Chaos: Niels Stensen's Chaos-manuscript* (Denmark: Danish National Library of Science and Medicine, 1997 [Copenhagen, 1659]), col. 24, 81, and col. 38, 124.

645 Bacon, *Advancement of Learning*, 69.

646 Bacon, *Advancement of Learning*, 69.

present. For example, 'the use of *history mechanical*' – that is, the '*history of nature wrought*' such as by the 'manual arts' of agriculture – 'is of all others the most radical and fundamental towards natural philosophy'.[647]

> For it will not only minister and suggest for the present many ingenious practices in all trades … but further, it will give a more true and real illumination concerning causes and axioms than is hitherto attained.[648]

First, having a history of how art has been used to manipulate nature, such as records of the tools and techniques used in the creation of arable land, provides people in 'the present' who are engaged in similar trades with 'ingenious practices' that can be improved upon. Second, since the 'true office' of history is 'to represent the events themselves together with the counsels, and to leave the observations and conclusions thereupon to the liberty and faculty of every man's judgement', the '*history of nature wrought*' is most 'fundamental' for natural philosophers who, by "observing" effects collected in various histories, gain 'a more true and real illumination' of 'causes and axioms'.[649] Bacon underscores the novelty of his approach in the *Preparative towards a Natural and Experimental History* (1620), boasting that 'neither Aristotle, nor Theophrastis, nor Dioscorides, nor Caius Plinius ever set this before them as the end of natural history'.[650] The move from histories to hypotheses is an inductive step.[651] Because histories are written "evidence", Bacon stresses the importance of 'the method in which the history should be composed', stating that the intended end justifies the means of the narrative.[652] This is what Hooke and Steno have as their idea of history, though both modify it to suit their needs and purposes, and since fossils are history, or, as I argued earlier, the past tangibly present, it is necessary to examine Bacon's programme in a little more detail.

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647 Bacon, *Advancement of Learning*, 72.
648 Bacon, *Advancement of Learning*, 72–73.
649 Bacon, *Advancement of Learning*, 79, 73
650 Francis Bacon, *Preparative towards a Natural and Experimental History*, in *The Works of Francis Bacon, Volume 4* (Cambridge: Cambridge University Press, 2011 [1858]), 254.
651 Bacon, *Preparative towards a Natural and Experimental History*, 253–254.
652 Bacon, *Preparative towards a Natural and Experimental History*, 254.

Bacon's argument, that historiography is crucial not only for present knowledge but its future betterment, is most explicit in *New Atlantis*, where the pre-eminent act 'amongst the excellent acts of that king [Salomon]' was the erection of 'Salomon's House'.[653] The House, composed of several laboratories and workshops, 'dedicated to the study of the Works and Creatures of God', acquires much of its knowledge from 'records'. These records, as well as the historiographers of Salomon's House, empower their 'Fellows' by providing them with 'some parts of … works', secret knowledge, to others 'lost':

> Some think it bereath the founder's name a little corrupted, as if it should be Solamona's House. *But the records write it as it is spoken*. So as I take it to be denominate of the King of the Hebrews, which is famous with you, and no stranger to us. For *we have some parts of his works which with you are lost; namely, that Natural History which he wrote*, of all plants, from the *cedar of Libanus* to the *moss that groweth out of the wall*; and of all *things that have life and motion*.[654]

Bacon invents several telling titles for the historiographers and archivists of the House: for example, twelve 'Merchants of Light', doubtless alluding to the twelve apostles, are tasked with travelling 'into foreign countries' as spies to 'bring us the books and abstracts and patterns of experiments'.[655] Just as the microscope in a sense makes a new world (recall '*there is a new visible World discovered to the understanding*', Hooke concludes in the *Micrographia's* preface),[656] Bacon's histories are intellectual instruments that help craft knowledge and experiences, though not necessarily of 'what has happened'. Although Bacon has traditional, descriptive histories, he also has histories with a different end in mind: 'experimental histories', which spring from his belief in the value of artisanal knowledge as a way to manipulate nature, mixing how to know and how to do a thing. In this way, Bacon challenges Aristotelian conceptions about the role of history. Yet the new problem of time-as-

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[653] Bacon, *New Atlantis*, 137.
[654] Bacon, *New Atlantis*, 145. Italics added.
[655] Bacon, *New Atlantis*, 164.
[656] Hooke, *Micrographia*, *Preface*, unpaginated.

evidence in natural history would cast doubts on which histories could be trusted, and cause resistance to alterations in established, taken-for-granted timescales. We discussed spatio-temporal problems and benefits before in greater detail when analysing Hooke's work, and we will return to it next with Steno, who gave himself the task of attempting to prove, for example, the sequential physical changes of the six faces of the earth.

In contrast to history, Bacon claims that 'Poesy is a part of learning … extremely licensed, and doth truly refer to the imagination'. The imagination,

> being not tied to the laws of matter, may at pleasure join that which nature hath severed, and sever that which nature hath joined; and so make unlawful matches and divorces of things[.][657]

Because poetry can make 'unlawful matches and divorces', it cannot be trusted, and contrary to Aristotle's claim, has little use in philosophy. In relation to imagination, poetry 'is rather a pleasure or play of Imagination, than a work of duty thereof'.[658] As the second part of learning, it is 'for the expressing of affections, passions, corruptions, customs', and if used properly, can be relied upon to succeed 'in rude times and barbarous regions, where other learning stood excluded'.[659] In this way, 'because the acts or events of *true history* have not that magnitude which satisfieth the mind of man, poesy feigneth acts and events greater and more heroical', heightens vices and virtues.[660] Finally, and perhaps surprisingly, Bacon defines poetry thus: it 'is nothing else but *feigned history*'.[661]

It is interesting, then, that in the middle of Bacon's taxonomy of history, only 'unperfect histories' – fragments such as '*memorials*' and '*antiquities*' – can evade the touch of poetry.[662] For whole, intact, '*perfect history*', a subcategory of '*civil history*', *pretending* to represent, that is, *feigning* history, is necessary: poetry or *imagination* fills gaps in history or *memory*. In Bacon's

[657] Bacon, *Advancement of Learning*, 82.
[658] Bacon, *Advancement of Learning*, 82, 121.
[659] Bacon, *Advancement of Learning*, 83.
[660] Bacon, *Advancement of Learning*, 82–83.
[661] Bacon, *Advancement of Learning*, 90.
[662] Bacon, *Advancement of Learning*, 73–74

words, '*just* and *perfect* history, is of three kinds, *according to the object which it propoundeth or pretendeth to represent*'.[663] When natural philosophers like Hooke and Steno decide to "mix" civil and natural history in order to use the former as evidence for the latter, a practice against Bacon's programme and abhorred by him, the problems associated with feigning in civil history are transferred across to natural history. As shown in Chapter 5, Hooke "feigns" by attempting to extract empirical information (or 'experimental history') on Earth history, such as records of earthquakes and fossils, from civil history and myths to support his theory on earthquakes.[664] Bacon further segregates the subcategory of perfect history into times, lives and narrations, since 'it ether representeth a *time*, or a *person*, or an *action*'. For example, "times" 'representeth the magnitude of actions … and passeth over in silence the smaller passages and motions of men and matters'. Gaps such as these 'smaller passages' of non-moments are filled and given relevance with feigned history, and the narrative as a whole is dependent on the relation between the writer and the text, or by 'an argument comprehensible within the notice and instructions of the writer'. Thus, Bacon concludes 'he that undertaketh the story of a time, especially of any length, cannot but meet with many blanks and spaces which he must be forced to fill up out of his own wit and conjecture':[665] civil histories are products of histories "true" and "feigned". The introduction of evidential temporality into descriptive historical narratives creates the new problem of having to account for gaps and discrepancies in time, which are like an unreliable escapement (mechanical regulator) in a watch.

As the sixteenth century morphed into the seventeenth, early modern poets, playwrights and historians noted, in response to Aristotle, that if poets could historicise, then historians could poeticise. Some, determined not to stray far from the topoi assigned to them by Aristotle, reacted defensively. Some

[663] Bacon, *Advancement of Learning*, 74. Italics added.
[664] See also Birkett and Oldroyd, 'Robert Hooke, Physico-Mythology, Knowledge of the World of the Ancients and Knowledge of the Ancient World', 145.
[665] Bacon, *Advancement of Learning*, 74

went on the offensive. Bacon's contemporary Samuel Daniel, for example, in the opening of his verse history of the Wars of the Roses, subverts Aristotelian poetry by consistently invoking 'the Records of Memory', and stressing in the beginning that he can poeticise the structure without compromising the subject matter:[666]

> How causes, counsels, and euents did runne
>
> So long as these vnhappie times did last,
>
> [Intermixt?] with fictions, fantasies;
>
> I versifie the troth, not Poetize.[667]

Daniel styles himself as a "witness" of past actions, events and lives giving a 'publike Testimonie' of civil-historical facts, and interprets Cicero's 'first law of history' as an examination of primary sources 'without adding to, or subtracting from, the general receiu'd opinion of things as we finde them in our common Annalles'.[668] Historians, like 'diuers other antient and modern Writers' such as Herodotus, may use 'poeticall licence' stylistically; unlike poets, however, they do not 'introduce fictions of [their] owne imagination', for 'there are euer popular bruites, and opinions, which run according to the time and the biass of mens affections'.[669]

But some adopted Aristotle's predisposition to poetry with glee. Philip Sidney, a late sixteenth-century Aristotelian, in his famous *The Defence of Poesy* (published posthumously in 1595, the same year as Daniel's history), attacks the use of verisimilitude in historical texts, and draws attention to the blurring of

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[666] Daniel, The *ciuile wars betweene the howses of Lancaster and Yorke corrected and continued by Samuel Daniel …*, I.6. Lawrence A Scaff and Richard C McCoy, *The Rites of Knighthood: the Literature and Politics of Elizabethan Chivalry* (Berkeley, USA: University of California Press, 1989), 106–107; Edward Paleit, *War, Liberty, and Caesar: Responses to Lucan's Bellum Ciuile, ca. 1580–1650* (Oxford: Oxford University Press, 2013), 63–70; David Ian Galbraith, *Architectonics of Imitation in Spenser, Daniel and Drayton* (Toronto: University of Toronto Press, 2000), 90; Pugliatti, *Shakespeare the Historian*, 69–73.

[667] Daniel, The *ciuile wars betweene the howses of Lancaster and Yorke corrected and continued by Samuel Daniel …*, I.6.

[668] Marcus Tullius Cicero, and E W Sutton (trans and ed), *De Oratore* (Cambridge, USA: Harvard University Press, 1957), 2.62; Daniel, The *ciuile wars betweene the howses of Lancaster and Yorke corrected and continued by Samuel Daniel …*, unpaginated.

[669] Daniel, The *ciuile wars betweene the howses of Lancaster and Yorke corrected and continued by Samuel Daniel*, unpaginated.

boundaries between history and poetry when complaining that

> even historiographers, although their lips sound of things done, and verity be written in their foreheads, have been glad to borrow both fashion and perchance weight of the poets. [670]

In Sidney's sometimes sarcastic reformulation, historians steal from poetry because they style themselves as philosophers. Historians' 'greatest authorities are built upon the notable foundation of hearsay'; they 'pick truth out of partiality'; and are 'better acquainted with a thousand years ago than with the present age'.[671] And although for Aristotle, 'The work of Herodotus might be put into verse, and it would still be a species of history, with meter no less than without it', for Sidney, 'Herodotus … and all the rest that followed him either stole or usurped of poetry their passionate describing of passions, the many particularities of battles which no man could affirm'.[672] Bacon, too, was aware of this pitfall of history, namely, that 'accepting or admitting things weakly authorised or warranted', or that the 'belief of history', can lead to 'error':

> We see the experience and inconvenience of this error in ecclesiastical history; which hath too easily received and registered reports and narrations of miracles … to the great scandal and detriment of religion.[673]

But as one of the three parts of learning, Bacon blames poetry – not history or philosophy – for this error: 'For we see that, in matters of faith and religion, we raise our imagination above our reason'.[674]

In diametrical opposition to Bacon's distinction between reason and imagination, Sidney claims that only the poet can improve upon nature, not with memory, reason and truth, but with imagination, which frees him from 'what nature will have set forth':

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670 Sidney, *The Defence of Poesy*, 4.
671 Sidney, *The Defence of Poesy*, 13.
672 Aristotle, *Poetics,* Section I, Part IX.; Sidney, *The Defence of Poesy*, 4. See also Vine, *In Defiance of Time*, 13–15.
673 Bacon, *Advancement of Learning*, 28.
674 Bacon, *Advancement of Learning*, 130.

> Only the poet, disdaining to be tied to any such subjection, lifted up with the vigor of his own invention doth grow, in effect, into another nature, in making things either better than nature bringeth forth, or, quite anew, forms such as never were in nature, as the heroes, or demi-gods … so as he goeth hand in hand with nature, not enclosed within the narrow warrant of her gifts, but freely ranging within the zodiac of his own wit.[675]

That is, unlike Bacon shortly after him, Sidney argues that imagination *can* be trusted *because* it is not bound by matter. This completely contradicts Bacon's reasons for wanting an alchemical instauration at the turn of the century, the central thrust of which was discussed in Chapter 2: to sever all poetic practices from inquiries into true names, and replace them with histories, because an over-reliance on 'imagination and belief' rather than 'laborious and sober inquiry of truth' had corrupted such scientific investigations and *histories*.[676]

Moreover, poetry imbues truth with meaning. That is, poetry, being 'an art of imitation, for so Aristotle termeth it in his word ποίησις [*poiēsis*]'[677] is better suited to turning truths into lessons: for example, David's Psalms and Solomon's Song of Songs were written in verse for this reason.[678] However, Sidney warns that 'it is not riming and versing that maketh a poet … but it is that feigning notable images of virtues, vices' and so on. Thus poets are philosopher-priests, and historians, whether they versify or not, are the mongers of worldly wickedness: 'the historian, being captivated to the truth of a foolish world, is many times a terror from well-doing and an encouragement to unbridled

[675] Sidney, *The Defence of Poesy*, 7.

[676] Robert M Schuler (ed), *Alchemical Poetry 1575–1700: from previously unpublished manuscripts* (Oxfordshire: Routledge, 2013 [1995]), xxii. For the anti-establishment tradition, also see Dmitri Levitin, *Ancient Wisdom in the Age of the New Science: Histories of Philosophy in England, c. 1640–1700* (Cambridge: Cambridge University Press, 2015), 238. Francis Bacon, *Advancement of Learning*, 90.

[677] I am grateful to Ofer Gal for introducing me to Heidegger, who translates the definition of '*poiēsis*' as 'bringing-forth', and argues that '*Physis* also, the arising of something from out of itself, is a bringing-forth … *Physis* is indeed *poiēsis* in the highest sense. For what presences by means of *physis* has the bursting open belonging to bringing-forth, e.g., the bursting of a blossom into bloom'. According to Heidegger, the parallel of *poiēsis* in the arts is '*technē*' – that is, 'what is brought forth by the artisan or the artist': Martin Heidegger, 'The Question Concerning Technology', in Martin Heidegger, and William Lovitt (ed and trans), *The Question Concerning Technology and Other Essays* (Place unknown: Harper Collins, [1954] 1977), 10–11. This interpretation seems, to me at least, to be congruent with Sidney's apologia.

[678] Sidney, The Defence of Poesy, 9.

wickedness'.[679] Here, Sidney reveals his Protestant *contemptus mundi* attitude, at odds with the later physico-theology of Ray and indeed Steno.[680] In Sidney's conception, imagination does not make the poet superior to the historian because the mind mirrors nature, but because it is not bound by it, and is thus better than it.

Hayden White, in his work on the architectonics of historical narratives, offered some theoretical, allegedly novel insights on the amalgamation of historical and poetic elements, which restate and expound upon the above concerns with a skew towards poetry.[681] White argued that thinking historically necessitates choosing an interpretive strategy 'by which to explain or represent' the past by a narrative mode, that is, a process by which one determines or '*pre*figures the historical field'.[682] In a nutshell, tropological tools of interpretation are chosen for their explanatory effects, that is, for their ability to emphasise one historical perspective over another by crafting different narratives and thus meanings from otherwise messy and discontinuous historical facts.[683] According to White, prefiguring is a 'poetic act which precedes the formal analysis of the field', so that all research is mediated by the imagination.[684] But by concluding that the adoption of one perspective over another is based on aesthetic or moral choices, not epistemological ones, White fails to examine the shunning of the aspiration for narrative-independent "Truth" versus historical evidence symmetrically.[685] As outlined above with Sidney, Daniel, Bacon and others, epistemological choices are implicit in "prefiguration", and are expressed explicitly during conflicts. Verisimilitude is

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679 Sidney, The Defence of Poesy, 21.

680 For the *contemptus mundi* tradition, see Glacken, *Traces on the Rhodian Shore*, 162–163.

681 For more on why White's ideas are not novel, because Burnet and others had similar and better ideas in the seventeenth century, see Cindy Hodoba Eric, 'Artificial Apertures: The Archaeology of Ramazzini's De fontium in Seventeenth-Century Earth Historiography', 13.

682 Hayden White, *Metahistory: the Historical Imagination in Nineteenth-Century Europe* Baltimore and London: The Johns Hopkins University Press, 1973), x.

683 White, *Metahistory*, x, xi.

684 White, *Metahistory*, xi–x, 31; Hayden White, 'The Question of Narrative in Contemporary Historical Theory', in *History and Theory*, Vol. 23, No. 1 (February, 1984), 1–33, 33.

685 See also Peter Burke, 'Metahistory: Before and After', *Rethinking History*, 17, 4 (2013), 441; and for a balanced introductory analysis and critique of White's work, see Anne Green, and Kathleen Troup, *The Houses of History: A Critical Reader in Twentieth-Century History and Theory* (Manchester: Manchester University Press, 1999), Chapter 8.

not equivalent to the category of historical fiction, but fictionalised history; that the discourse is similar does not mean that it is the same. The attempt at ordering what-has-happened to contextually capture one's historical subject and give it thematic meaning, I would like to suggest, throws light on the intimate relations between the interpreter and the text, which do not necessarily pack into a prefigured genre, revealing reasons for differences in historical thinking and representation.

The difference between Hooke's and Steno's historicities, their scales and significations, underscores how the same content, in this case Noah's deluge, can be emphasised contrarily to back dichotomous arguments on natural history that nevertheless aim to persuade their audience to adopt a shared idea on what fossils are. In doing so, it further illuminates how Hooke's and Steno's "ancient" idea, that fossils are not generated in stone but are of organic origin, was used to write a history *from* nature; and how civil and sacred histories were reinterpreted to establish the authenticity of fossils as re-presentations.

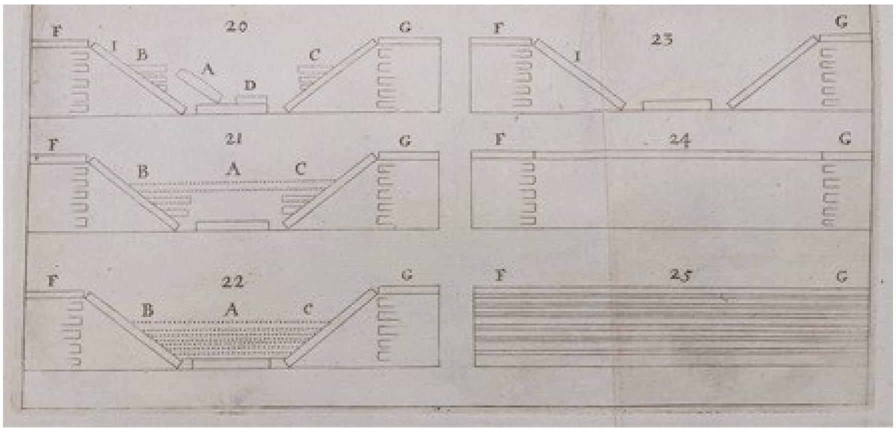


*Figure 9: Steno's diagrams of the six superficies of the earth, in his* Prodromus.

## 8.2 'AUTHORITY OF HISTORY'

As discussed in Chapter 6, Hooke's inversion of the themes of decay and ruin, his argument that they are 'universal' natural processes, compounds his cyclical worldview of 'a continual growth of Death and Decay' with the prophesied Biblical 'final Dissolution', enables him to enforce a pattern onto contingent past events. For Hooke, the deluge is one relatively unremarkable event in this dynamic process. For Steno, in comparison, the deluge marks a significant natural event because although something similar happened once before, when what Steno calls the earth's "first face" was covered in water, the dramatic changes that Noah's deluge incurred on the earth are distinctive enough to prohibit its repetition. To clarify, although ordinary natural events and stages can be repeated, the '*Six* distinct' faces (Figure 8) were extraordinary and sequential physical events that contributed to sculpting the earth's present superficies. A different superficies would require a seventh face to account for 'the order of the change'.[686] Therefore, to reject Hooke's cyclical account is to reject its implications: that, as put by Hooke, 'there may have been a preceding learned Age wherein possibly as many things may have been known as are now … annihilated, destroyed and lost by succeeding Devastations' just as 'there have been in former times of the World, divers *Species* of Creatures, that are now quite lost, and no more of them surviving upon any part of the Earth'. Moreover, according to Steno's worldview, if there had been a preceding learned culture, instead of the "wicked" one that the flood destroyed, then we would know about it from the Scriptures. Thus, as Cecil Schneer concluded, extinction is 'a logical necessity' for Hooke, whereas for Steno, as for Lister and Plot, it is 'an insuperable objection', or in Steno's words:

> as all the Solids of the Earth were in the beginning of things cover'd with an aqueous Fluid, so they may have been cover'd with it again, in regard that the change of natural things is indeed continual, but there is no Natural Annihilation.[687]

Although this seems self-contradictory, as explained above, there is a difference between the possibility of repeated stages – such as that the earth had been covered in water before God separated it from the land versus the universal flood of Noah – and cycles, because each preceding state or "face" of the earth sets up the physical conditions that allow for the next "face".

In constructing a narrative to support his claims on fossils and changes to the earth's surface that weaves '*Nature* with *Scripture*', with Noah's flood as its

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[686] Steno, *Prodromus*, 112.

[687] Cecil J Schneer, 'The Rise of Historical Geology in the Seventeenth Century', (Isis, Volume 45, No. 3, September 1954, 256 –268), 267. Steno, *Prodromus*, 102.

decisive moment, Steno faces two problems: time and place. In answer, he turns the end of the *Prodromus* into a study of the history of '*Etruvia* or *Toscany*' since the time of the flood. He is aware of the argument, advocated vehemently by Hooke, 'that the length of time', that is, '4000 Years', is perceived as too short a duration for such changes:

> Some there are, to whom it seems, that the length of time overthrows the force of all other Arguments; considering that 'tis recorded by no Age that Inundations have gone up so far as those places, where now many Marine Bodies are found, excepting the Universal Deluge; from the time of which there are reckon'd about 4000 Years to these our days.[688]

Putting these limitations on his narrative – change but no extinction; great displacement but only one deluge with mechanisms like Noah's – Steno's challenge, then, is to convince his readers that 'Marine Bodies' dug out of mountains date back to Noah's Flood: ''tis certain, that the production of many Shells, we meet with in our days, is to be referr'd to the times coincident with the General Deluge'; moreover, that ''tis evident, that in 4000 Years there have happen'd many and various Mutations'. In other words, '4000 Years' is enough time for marine bodies to end up petrified in rock formations. Steno interweaves civil, sacred and natural history by employing three working rules: first, 'Scripture and Nature' should 'agree'; second, where 'Nature is silent', often 'Scripture is not'; third, when both are 'silent', he relies on his own observations ('from many places attentively view'd by me'), or on 'Descriptions' from contemporaries as well as 'the writings of the Antients', provided that there is no conflict with sacred history.[689] Although Steno avoids the exegesis of ancient myths favoured by Hooke, he nevertheless defends, for example, the story of Atlantis as an event that actually happened, as well as the notion that the available traces of a 'History of Changes', although scattered, do provide reliable evidence of four thousand years of 'Earthquakes, Eruptions of Fires, Inundations of Rivers and Seas' and so on.[690]

688 Steno, *Prodromus*, 89–90.
689 Steno, *Prodromus*, 99–109.
690 Steno, *Prodromus*, 108–109.

In this way, Steno both criticises the dogmatic attacks of historical sceptics that question the reliability of ancient sources, and chooses to base his analysis and interpretation of the past on grounds that he considers to be moral – in keeping and cohering with his Stoic ideals of an inherently moral physics that is common to all – and the ancient opinion on the origin of fossils.[691] Again, 'If, I say, we shall grant these particulars, we shall grant nothing contrary to reason nor daily experience'.[692] Thus, with ancient sources treated cautiously as civil or natural histories, Steno forms relations between them, the Scriptures and his empirical observations to ensure historical authenticity when supporting his claims on each transformation of the earth's surface.

The earth's first face, made of horizontal 'Beds of simple matter' was 'all … cover'd by a fluid, destitute of Plants, Animals and other Solids'; the second face was 'Plain and Dry'; the third, 'Craggy', that is, made of mountains and valleys.[693] However, most crucial for fossils 'enclosed in strata is the transformation caused by the 'Universal Deluge', that is, the earth's '*Fourth* Face, when all was Sea', which 'seems to have more difficulty in it' and which Steno spends the most amount of text on.[694] Here, he uses his now famous notions on the superposition of strata to argue that the earth's third 'Craggy' face, caused by water erosion collapsing horizontal layers of strata into one another, created an environment in which a 'Universal Deluge' *could* happen. Therefore, 'fallen fragments of some Beds' blocked the flow of water, and 'subterraneal fires' pushed and thrust the water out through springs and other pores 'into the Air', where it precipitated into rain. The rain in turn washed sediments down, clogging the earth's remaining caverns, cavities and crevices, and together, these events caused the sea to elevate over the highest mountaintops.[695] Steno remarks that 'the highest Mountains,

[691] For seventeenth century disputes on the reliability of ancient sources, see Anthony Grafton, *What was history? The art of history in early modern Europe* (Cambridge: Cambridge University Press, 2007).
[692] Steno, *Prodromus*, 105.
[693] Steno, *Prodromus*, 99–101.
[694] Steno, *Prodromus*, 101.
[695] Steno, *Prodromus*, 104–105.

mention'd in Scripture, were the highest of those Mountains, that were to be found *at that time, but not of those at this day*', absolving himself of having to also answer the problem of the amount of water not being enough for a *universal* deluge, as attempted painstakingly by Stillingfleet and many others (Chapters 4 and 5). Yet it is a claim supported by the same *deus ex machina* appeal to 'the First Mover' – an active force capable of producing effects 'repugnant to the ordinary Laws of Nature' just as man can "alter the course of rivers" or drain marshes – that Steno used to explain 'the first and unknown Cause of Motion' when outlining his common physics.[696] For extra scaffolding, he turns to civil history: 'About the Time of the *Universal* Deluge, Civil History is not repugnant to Sacred, reciting all things concerning it particularly'. Providing a local example, he explains that the 'ancient Towns of *Etruvia*' or Tuscany were founded 'above Three Thousand Years' ago, and some are 'built on Hillocks produced by the Sea'. Moreover, 'in *Lydia* we approach nearer to Four Thousand Years; whence it may be infer'd,' he argues, 'that the time, when the Earth was relinquish't by the Sea' confirms 'the time, which the Scripture mentions'.[697]

Since Steno's fieldwork is limited to Tuscany and its surrounds, in his version of events, he needs to account for 'various Mutations' in the '4000 Years' post-flood to this particular place, historically hence causally. Further, to generalise from these local events, Steno uses Tuscany as a synecdoche for the whole earth, inverting his preferred way of working a problem:

> as I make it out to be true of *Etruvia*, from many places attentively view'd by me; so I confirm it to be true of the *whole Earth*, from the Descriptions of many places deliver'd by divers Authors.[698]

But to piece together a chronicle, Steno employs a technique allegedly first attempted by 'the founder of Christian chronology' Theophilus of Antioch (115–81 CE) when working backwards to determine the date of Adam and Eve.

[696] Steno, *Prodromus*, 103; also see pages 16–17 for comparison. Italics added.
[697] Steno, *Prodromus*, 103
[698] Steno, *Prodromus*, 96. Italics added.

More concerned with sequential physical changes, Steno reconstructs a case history 'by an *inverted order*, and a *retrogradation* from the last to the first', which he attempts to visually reinforce with six diagrams that show 'how from the present face of *Etruria*' one can 'collect the six distinct faces', and imagine 'the order of the change'.[699] Although Steno refuses to discuss the "first delineations" of material things, his reasons for 'an inverted order' are the same as Hooke's when the latter likens insensible objects to insensible history (Chapter 5.2). That is, just as Hooke argues that studying insensible history is like analysing the microscopic 'Marks or Characteristicks' of fossils in the sense that the fragmented minutiae of natural history in civil histories, myths and so on, though tiny are still significant, similarly Steno's inversions afford him a means to peer past what is possible to "observe" in a human lifespan.

For example, Steno appeals to the 'authority of History, which will not let us doubt', when arguing 'that vast Bones' dug up from the '*Aretine* [Arezzo] Fields; have lasted 1900 Years,' and lists five reasons why 'every one, that shall but compare the condition of the place, and the Kind of Bones with the History, will find all things evidently agree together'.[700] First, 'the Skuls' and other bones 'of labouring Beasts, found there' are foreign to the climate; second, Hannibal passed through Arezzo en route to the Battle of Lake Trasimene (217 BCE); third, Hannibal's army had '*African* Beasts, and huge Turret-bearing Elephants'; fourth, 'the greatest part' of the pack animals in Hannibal's army 'perished by the Waters in the Marishes' when he descended the Fiesole mountains; finally, Steno ends by incorporating his hypothesis on sedimentation and strata formation into the narrative: 'the place, whence the said Bones are digg'd, was heaped up by various Beds, that are full of Stones thither devolved from the circumjacent Mountains by the impetuousness of Torrents'.[701] Just so, Steno says, ''tis certain, that the production of many Shells, we meet with in our days, is to be referr'd to the times coincident with the General Deluge'.[702]

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[699] Steno, *Prodromus*, 96, 112. For Theophilus, see Oldroyd, *Thinking about the Earth*, 22.
[700] Steno, *Prodromus*, 92–93.
[701] Steno, *Prodromus*, 92–93.
[702] Steno, *Prodromus*, 90.

On the one hand, for regular shells 'taken out of the Sea', Steno notes four 'particulars' about their production, which all 'sorts of *Shells*, that once had an animal in them, *exhibit to our senses*'. To summarise, he reduces a whole shell to what Oldenburg translates as 'little shells',[703] and these further into 'Threds' or filaments, explaining that 'the Matter of Threds is like the sweat of Animals in this, that it is an humour excreted through the exterior superfice of the Animal'. While the diversity of filaments depends upon 'the difference of the Pores, to be found in the superfice of the Animal, and from the difference of the matter that is excreted by the same pores', variety is once again caused by place: oysters, for example, obtain 'their [exterior] figures not from themselves [their "excretions"], but from the place'.[704]

On the other hand, Steno categorises '*Shells* that lye under ground' into 'three sorts'. First, petrified shells that 'are so alike to those [seashells] lately described, as an Egg is to an Egg', because like seashells, they too can be 'resolved into *litle Shells*, and the little Shells into Threds'. Second, and in agreement with Hooke's observations in the *Micrographia*, are 'those Shells' that differ 'only in colour and weight; in regard that some of them are found too light, others too heavy, for as much as *these* have pores fill'd up with an adventitious juyce, but the pores of *those* are widen'd by expulsion of the lighter parts'. Finally, the '*Third* sort, is of such as in their figure alone resemble' seashells, 'but for the rest totally differ from them, seeing that in them are to be found neither the little Shels, nor the Threds, much less the diversity of Threds'. Fossilised molluscs of this third sort are either what Steno calls '*Lapideous*', '*Marbly*', or '*Chrystallin*', based on their physical appearance, which depends upon how 'the penetrating force of juyces', interacting both with the matter of the shell and its place, 'hath dissolved the [original] substance of the Shell'.[705] Thus, according to Steno, studying the '*place'* where a fossil is found,

[703] Kardel and Maquet translate 'little shells' as 'testulae', also noting that John Garrett Winter, in his English'd 1916 edition of Steno's *Prodromus*, 'translates "testulae" as "subdivisions" Krogh and Maar in note 10 as "scales" of the shell': Kardel and Maquet, in Steno, and Kardel and Maquet (eds), *Nicolaus Steno*, 647. Italics added.

[704] Steno, *Prodromus*, 76–78.

[705] Steno, *Prodromus*, 81–85.

empirically and historically *hence causally*, as well as the sensible makeup of the fossil itself, hints 'how from that which is sensible, something certain may be concluded about that which is not sensible'. Or, 'How the *Present* state of a thing may discover the *Former* state of the same'.[706]

Applying the above types of comparative analyses to Tuscany and its surrounds, Steno turns his attention to the 'Sixth' or 'present face' of the earth by investigating the history of the 'town of *Volaterra* [Volterra]' – the 'most ancient Town' of the Etruscans.[707] According to him, the rock upon and from which Volterra was built rose 'out of the sediments of the Sea, laid on one another, and parallel to the Horizon', and 'all sorts of Shells' can be found in the 'very ancient Walls' as well as in stone hewn from 'the midle of the Market-place'. Not only petrified shells, Steno stresses, but 'unchanged' ones, too, which 'were already produced at the time when the *Volaterran* walls were rais'd'.[708] By compounding this local history and his observations, he concludes that

> we may confidently say, that those Cockles, which at this day we have drawn from thence, and that are unchanged, have been produced *Three Thousand Years ago, and more*.[709]

But when it comes to making up for the one thousand year or so gap required to date the 'unchanged' and petrified shells of Volterra to the time of Noah's flood, owing to discontinuities in the histories, Steno resorts to introducing speculative elements into his timeline by "poeticising" or "feigning", in Bacon's sense, what may have happened. Although 'Civil History is not repugnant to Sacred' *during* the deluge in Steno's rendition, sacred history is 'silent' about what happened *after* 'the *Fifth* Face', when the flood

[706] Steno, *Prodromus*, 96.
[707] Steno, *Prodromus*, 90, 91. According to Leighton, as an archaeological site Volterra was 'already occupied in the Final Bronze Age (Protovillanovan period, twelfth to eleventh centuries), or even earlier': Robert Leighton, 'Urbanization in Southern Etruria from the Tenth to the Sixth Century BC: the origins and growth of major centers', in Jean MacIntosh Turfa (ed), *The Etruscan World* (London and New York: Routledge, 2013), 134.
[708] Steno, *Prodromus*, 90–91.
[709] Steno, *Prodromus*, 91. Italics added.

receded and the earth was 'made dry again'.[710] The 'History of Nations about the first Ages from the Deluge is doubtful to the Nations themselves, and hath been believed full of Fables', so that 'we may not determine anything certain thereof'.[711] Here, like Hooke earlier, Steno echoes Bacon, who noted that one deficiency of civil history is that '*heathen antiquities* of the world' consist mostly 'of fables and fragments'.[712] Steno further complains that 'the history of the first Ages after the Floud is confused and dubious amongst Profane Authors; and in the after-Ages [after the "sixth face"] they undertook to write and celebrate the Actions of renown'd Men, and not the wonders of Nature'.[713]

Nevertheless, Steno wants both to convince his readers that fossils are of organic origin and that they were moved from their natural place by Noah's flood. He makes assumptions on how long it might have taken for 'the town' to come into existence and develop, so that he can date the fossils back to the deluge. For example, Volterra was already powerful before the foundations were laid for Rome, and 'until these times we reckon about 2420 Years'; moreover, 'many Ages elapsed from the time that the first People seated themselves there until the place grew to that bigness'; and 'that time, which passed from laying the first sediment of the Volaterrian Hillock, to the time when the same was relinquish't by the Sea, and the Aliens there settled'.[714] Whether or not broad conjectures like these compromise the veridicality of Steno's careful studies of the Tuscan landscape as well as his historical-causal narrative, for him it is a price worth paying, because it prevents incoherence between the Scriptures and his observations of nature: it makes his account of fossil formation *a part of* that sacred history.

Thus, Steno maintains that with the addition of these sweeps of time, 'we shall easily come up to the very times of the Universal Deluge' for the age of Volterran cockles. With these moves, he makes a moral choice, in adherence with his inherently moral, common physics, to order his natural-historical

710 Steno, *Prodromus*, 103, 106.
711 Steno, *Prodromus*, 106.
712 Bacon, *Advancement of Learning*, 75.
713 Steno, *Prodromus*, 107.
714 Steno, *Prodromus*, 91–92.

experience according to his civil- and sacred-historical exegesis. Indeed, it is unimaginable to Steno that his account of fossils should not cohere with his other beliefs. According to Steno's physics, the Noah's flood explanation for fossils makes the most common sense.

## 8.3 'From the Light of History or Records'

The amalgamation of empirical evidence with histories, Cecil Schneer argued, hails from antiquaries rubbing shoulders with natural philosophers, an important outcome of which contributed to a geological turn in the seventeenth century, and in Hooke's work on fossils and earthquakes.[715] This is evident in Hooke's move away from simply collecting found natural objects like fossils, and treating them as objects of wonder, a practice disparaged by him, to treating fossils as 'Monuments and Records to instruct succeeding Ages of what past in preceding' – natural urns and coins, as it were. Namely, learning how to examine nature and to construct a natural history by adopting the techniques associated with the study of civil history – exactly what Steno attempts as well with his own collection of Tuscan fossils and soil samples.[716] In this way, Hooke not only compounds categories of civil and natural history, extracting the latter from the former, as mentioned earlier when discussing Bacon's histories, but also translates Bacon's visual metaphors from civil history to natural history to argue that fossils are nature's antiquities. Bacon likens civil history to 'three kinds of pictures or images: for of pictures or images, we see some are unfinished, some are perfect, and some are defaced'. Like Hooke's comparison of fossils to artificial remains, the excavation of civil histories, according to Bacon, unearths either a perfectly intact object; or '*memorials'*, which are 'history unfinished, or the first or rough draughts of history'; or '*antiquities'*, namely, 'history defaced, or some remnants of history which have casually escaped

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[715] Schneer, 'The Rise of Historical Geology in the Seventeenth Century'. Also see Simon Schaffer, 'Halley's Atheism and the End of the World', *Notes and Records: the Royal Society Journal of the History of Science*, Volume 32, Issue 1 (31 July 1977, 17–40), 25. For an account of the role of antiquarianism in creating an early modern English historiographical approach as well as a historical culture, also see Daniel Woolf, 'Horizons of early modern historical culture'.

[716] Kardel and Maquet, in Steno, and Kardel and Maquet (eds), *Nicolaus Steno*, 207–208.

the shipwreck of time'.[717] Yet, it is worth repeating, treating fossils as antiquities, Hooke does not turn them into curios or mere objects of 'Divertisement, Wonder, and Gazing', but into part of 'a Collection of all varieties of Natural Bodies', which allow an 'Inquirer' to 'as with a *Dictionary* … turn to and find the true Figure, Composition, Derivation and Use of the Characters, Words, Phrases and Sentences of Nature written with indelible, and most exact, and most expressive Letters'. In giving fossils their own visual language, etymology and so on, Hooke tries to create a typology with which to teach his audience 'the *Orthography, Etymologia, Syntaxis*, and *Prosodia* of Natures Grammar', and thus to 'peruse, and turn over, and spell, and read the Book of Nature'. But Hooke, as Schneer put it, indirectly 'read[s] God out of nature'[718] by changing the face not only of the earth, but necessarily its history.

### 8.3.1 'Natural Antiquary'

The competing intellectual traditions and agendas that I have been discussing throughout, with their ontological worries and resultant epistemologies, were inseparable from the practical problems and cultural attitudes related to the earth and its resources, further fuelling differences about how much the history of the earth should be subjected to new investigative procedures. For example, water management via piston pumps was a necessity for miners, because digging deeper into the earth, to follow veins of dwindling ore, caused mines to flood with groundwater; but piston pumps had an operating limit of 32 feet, and it was hard to suck water out of mines past even 10 feet.[719] This problem was famously tackled by Galileo and his disciple Evangelista Torricelli, leading to the phenomenon of the 'Torriceallian space' (what Hooke calls the '*AEthereal Vacuum*' at the top of a mercury barometer).[720] In

[717] Bacon, *Advancement of Learning*, 74.

[718] Cecil J Schneer, *Mind and Matter: Man's Changing Concepts of the Material World* (New York: Grove Press, Inc., 1969), 56–57.

[719] Schneer, *Mind and Matter*, 56–57; Ofer Gal, *Meanest Foundations and Nobler Superstructures*: *Hooke, Newton and the 'Compounding of the Celestiall Motions of the Planetts'* (Dordrecht: Kluwer, 2002), 54; Hooke, *Micrographia, Observ. LVIII. Of a new Property in the Air …*

[720] Hooke, *Discourse of Earthquakes*, 365; Schaffer and Shapin, *Leviathan and the Air-Pump*, 41.

Florence, from 1643 to 1644, Torricelli performed a series of trials on columns of water and mercury in an attempt to show that the 32-foot limit for water was caused by atmospheric pressure, and that changes in atmospheric pressure would alter a column's height (an experiment that Florin Périer, Blaise Pascal's brother-in-law, tried by carrying a mercury barometer up a mountain, and that Hooke later attempted to improve upon in the *Micrographia*).[721] Boyle and Hooke's air-pump or '*Pneumatick* Engine' was, to a degree, an outcome, continuation and elaboration of these studies – of peering at nature artificially isolated – which brought to stark relief the paradox that nature can only be properly experienced and understood through art.[722] Hooke's hybridisation of art and nature, his use of fossils as antiquities, is another outcome of this new way of thinking about and approaching nature through art.

In England, around two decades after Torricelli's experiments, the antiquary and herald William Dugdale, known for turning local and family history into 'gentry pedigrees' as well as for writing the doorstopper *The Antiquities of Warwickshire Illustrated*, published his "propagandist" and "partisan" *history of imbanking and drayning of divers fenns and marshes …*, during the drainage of the largest region of the Fens, the Great Level – an engineering project that controversially manipulated nature on a grand scale.[723] According to Eric Ash, the fens project exposed deeply entrenched and opposing perceptions about nature and artificial changes to the natural environment. For defenders of orthodoxy, the marshes were already pristine. But Dugdale, firmly a 'pro-drainage' campaigner, depicted nature as 'reactive and malleable' – similarly to Gilbert, Hooke and Steno – and for him, as further emphasised by Ash, the fens were 'a divine challenge to the industry and ingenuity of mankind to complete God's efforts to separate the water

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721 Schneer, *Mind and Matter*, 56–57; Gal, *Meanest Foundations and Nobler Superstructures*, 54; Hooke, *Micrographia*, *Observ. LVIII. Of a new Property in the Air …*

722 Gal and Chen-Morris, *Baroque Science*, Part 1.

723 Frances Willmoth, 'Dugdale's "History of Imbanking and Draining: a "Royalist" Antiquarian in the Sixteen-Fifties' (*Historical Research*, Volume 71, Issue 176, October 1998), 281–302. Eric H Ash, 'Amending Nature: Draining the English Fens', in Lissa L Roberts, Simon Schaffer and Peter Dear (eds), *The mindful hand: inquiry and invention from the Late Renaissance to Early Industrialisation* (Chicago: University of Chicago Press, 2007), 117–143.

from the land'.[724] Dugdale represents a new form of mid-seventeenth century antiquary for two reasons: his use of non-local history to further buttress his arguments;[725] and his interest in digging up not only objects of art like coins, but also natural objects such as long-buried trees and fossils, for the purpose of establishing a chronology. For these reasons, and more importantly his indirect intellectual ties to Hooke on the topic of the earth's changing superficies and fossils, Dugdale is a good example of an antiquary whose fieldwork descriptions were used as resources by natural philosophers.

The lengthy title of Dugdale's work boasts to be on no less than the history of the art of 'Imbanking and Drayning' from local as well as 'Forein Parts', with 'Records, Manuscripts, and other Authentick Testimonies' as reliable evidence, which Dugdale supplements with empirical observations, his own and others', of what Schneer called 'fossil evidence'.[726] That the art of 'Drayning' is 'most antient, and of divine institution, we have the testimony of the holy Scripture': thus, Dugdale opens his history with *Genesis*, citing God's separation of the land from the water as well as that this act caused the growth of 'grass, and herb yielding seed, and the fruit tree'.[727] He then cuts to the end of Noah's flood when, 'Again, after the Deluge, it was through the divine goodness, that *the waters were dryed up from off the Earth, and the face of the ground was dry*'.[728] Dugdale's main claim here lies hidden between the divine drainage of

[724] Ash, 'Amending Nature: Draining the English Fens', in Roberts, Schaffer, and Dear (eds), *The mindful hand,* 127.

[725] Daniel Woolf argued that antiquaries traditionally placed primacy on space over time in their surveys and records, taking care to document artificial spatial boundaries of cultural importance like marker stones and consecrated land. Woolf noted that texts like Dugdale's *Antiquities of Warwickshire* blurred these boundaries as well as the antiquarian genre by incorporating broad history into local and familial accounts, and in so doing, placing importance on chronology and events over space. Nevertheless, 'natural histories' such as Plot's continued to observe traditional antiquarian practices: Woolf, 'Horizons of early modern historical culture', 106–111 (see also footnote 40). For mid-seventeenth century antiquaries and fieldwork, see also, Graham Parry, 'Thomas Browne and the Uses of Antiquity', in Reid Barbour and Claire Preston (eds), *Sir Thomas Browne: The World Proposed* (Oxford: Oxford University Press, 2008, 63–79), 74–75, and Graham Parry, *The Trophies of Time: English Antiquaries of the Seventeenth Century* (Oxford: Oxford University Press, 1996), 245.

[726] Schneer, 'The Rise of Historical Geology', 265.

[727] *Genesis* 1:11–13 (KJV).

[728] William Dugdale, The *history of imbanking and drayning of divers fenns and marshes …* (London: Printed by Alice Warren, 1662. Early English Books Online Text Creation Partnership, http://name.umdl.umich.edu/A367795.0001.001, re-accessed 22/12/22), 1. (Henceforth:

the waters of Creation and the deluge: drainage exposes fertile soil, which in turn is good for 'industry'. Accordingly, and rather alchemically, the onus is on Man, made from earth in God's image, 'to compleat and make perfect that Noble undertaking' so that the 'good Arts may again flourish' for the benefit of 'industry'.

Similarly to Hooke, then, who, recall, favours Lower Egypt in his argument that ancient historical accounts of the earth's changes are "matters of fact", Dugdale claims that the Ancient Egyptian civilisation was 'more mervailous than any other' in the study of water management because Egyptians had to devise ways to control the annual flooding of the Nile. 'We may therefore esteem the *AEgyptians* to have been the first Masters in this Art of Drayning', Dugdale concludes, ending with a powerful and provocative quote from the 'the learned Author' Strabo: '*their workman-ship about the River Nilus, being such … that their Industry surpassed nature*'.[729] That is, 'when nature was defective', the Egyptians, 'by the help of Trenches and Banks', improved upon it, thereby, in Dugdale's Christian retelling, completing "the divine work". Here, in the physical making, is Hooke's reversal of Lister and Plot's claims that human hands and art cause changes to the earth's otherwise pristine superficies: the fens project provides another, much more local instantiation of Hooke's notion that art is responsible for *stopping* natural changes, eventually erasing natural history by erasing nature's changes from human memory, so that in time the artificially created, stable environment is remembered as natural. In this sense, the fens controversy can be thought of as the question of whether one continues to uphold the stasis of pristine nature or accepts the concept of reactive and dynamic nature. The static understanding of nature engrained in the orthodox view is upheld by the concept of fossils as natural objects generated in stone or *lapides sui generis*; in contrast, the dynamic view of nature, promoted by Hooke, Steno and others (including Dugdale's friend

*History of Imbanking and Drayning*.)

[729] Dugdale, *History of Imbanking and Drayning*, 1. For the reference omitted by Dugdale, see James Sharp, *An Address ... on the importance and great utility of canals in general* ... (London: Publisher Unknown, 1773), 13; see also, Strabo, *Geographica*, lib. Xvii, 787.

Thomas Browne, mentioned in Chapter 2 with respect to alchemy, and whom we will meet momentarily), is expressed in fossils as objects of organic origin, with their own spatial and temporal complexity.

Dugdale's fens findings were brought up and discussed at a couple of Royal Society meetings in 1664 – in between Hooke and others chatting about "magnetical experiments" as well as debating how best to play with flammables and explosives, and Boyle showing off some curious pieces of iron ore – two years after the publication of *History of Imbanking and Drayning,* and one year before the *Micrographia.*[730] Upon Robert Moray expressing his interest in finding out how 'the wood of Hatfield-chace in Yorkshire' was 'altered' after having been 'buried there by a deluge, and the place afterwards drained', Walter Charleton proposed that the Society read Dugdale's 'account of this place in his *History of imbanking and draining*', and so 'the amanuensis was ordered to borrow that book of Mr. MARTYN, for the use of the Society, against the next meeting'.[731] The following meeting, Dugdale's book was 'produced', and Moray's interest in natural alterations was indulged by a reading of Chapter 27.[732]

Dugdale describes the 'Fenny tract' in detail, which although 'for many ages' has been 'covered with waters', had once upon a time been 'a woody Country'. He is 'assured from ocular testimony' that this 'is most evident by the great numbers of Oak, Firr, and other Trees [usually found in mountainous regions], which have been lately found in the Moor, upon making of sundry Ditches and Chanels for the drayning thereof'.[733] For example, 'Oak Trees', exposed after draining, are found

> lying somewhat above three foot in depth, and neer their roots, which do still stand as they growed … and the bodies, for the most part North West from the roots, not cut down with Axes, but burnt asunder somewhat neer

[730] Birch, *The History of the Royal Society of London*, Vol. 1, 448–451.
[731] Birch, *The History of the Royal Society of London*, Vol. 1, 448.
[732] Birch, *The History of the Royal Society of London*, Vol. 1, 450.
[733] Dugdale, *History of Imbanking and Drayning*, 141.

> the ground, as the ends of them, being coalled, do manifest … [some] with good quantities of Akorns neer them[.][734]

Dugdale also makes a note on superposition, that 'the Firr Trees do lye a foot, or eighteen inches deeper', though many are rotten 'through a long time of stagnation by the fresh waters'. But, in his published account, he remains cautious when it comes to making claims about 'the time when this woody Level … became first thus overflowed':[735]

> I can say nothing, there being not any memorial thereof transmitted to us, from the light of History or Records: but that it hath been so, for divers hundreds of years, the depth of the Moor doth sufficiently manifest; which could not, in a few Ages, grow to that thicknesse of it.[736]

Nevertheless, despite the lack of a 'memorial', Dugdale also conjectures that the cause of this sedimentation is

> the muddinesse of the constant tides, which flowing up *Humbre* into *Trent*, did in time leave so much silt to obstruct the currents of *Idle*, *Done*, and other Rivers … they flowed back and overwhelmed that Country with water; insomuch as the high ground became an Island [the Isle of Axholme], as it is still (we see) called.[737]

Schneer highlighted this conjecture in his paper 'The Rise of Historical Geology', because of Dugdale's revealing account of sedimentation and superposition: 'Here in the simplest form was the idea of superposition and of an historical process revealed in a natural record'.[738]

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734 Dugdale, *History of Imbanking and Drayning*, 141. Although Dugdale mentions, in a letter to Thomas Browne, that he has observed similar instances of trees dug up after the draining of a fen 'at Thorney', it seems that he never saw the Hatfield oaks first-hand: William Dugdale, and William Hamper (ed), *The Life, Diary, and Correspondence of Sir William Dugdale* … (London: Printed for Harding, Lepard, and Co …, 1827), 348–349.
735 Dugdale, *History of Imbanking and Drayning*, 141.
736 Dugdale, *History of Imbanking and Drayning*, 141.
737 Dugdale, *History of Imbanking and Drayning*, 141.
738 Schneer, 'The Rise of Historical Geology', 265–266. It should be noted that Schneer, having relied solely on the Royal Society reading of Dugdale's text, neglects to mention that not all of Dugdale's 'observations' were first-hand.

### 8.3.2 'EARTHQUAKES'

In the midst of a correspondence with Thomas Browne, a physician, and follower of Bacon's, also learned in natural philosophy, alchemy, and religion, whose 'opinion' Dugdale sought on the history and state of the fens, he suggests that the mouths of rivers silted up over time, causing flood waters to turn stagnant. To Dugdale's conclusion, Browne replies with a detailed account of superposition: 'For the times when great mutations happened, or when things lately discovered were lodged under ground, consideration must be made of the lower soyle, of the siltie soyle, and of the soyle above it'.[739] That is, the three layers are a chronograph, and Browne expands upon them thus:

> The lower ancient, and proper soyle was laid, when the Rivers had their free course and egresse, when the baye was deepe, not clogged with sands, and the mouthes of the outletts free. The siltie soile might be laid when the flouds at higher tides came farr, when the baye being shallowed made the flouds large, and carried farr over the level … The fenny soile was raised when the sea was restrained, by art and nature, and the land flouds settled their mudd upon it[.][740]

If one could work out 'these several times', Browne restates, then 'some guide may be had to several doubts arising concerning the possibilities and time of such substances [which] are found' buried in the fens.[741] Yet as soon as temporal considerations were factored into Dugdale and Browne's discussion, so was Noah's flood. More important, agreeing about the importance of Noah's flood still left much concerning fossils to disagree on – even amongst the organic origins and dynamic nature proponents. On this side of the fossils controversy, how fossils represented opposing intellectual interests and motives is expressed in the subtle nuances between Dugdale's, Browne's and Hooke's treatment of them.

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[739] Thomas Browne, and Geoffrey Keynes (ed), *The Works of Sir Thomas Browne,* Vol. 4 (London: Faber & Gwyer, 1928–1931), 320.
[740] Browne, in Browne and Keynes (ed), *The Works of Sir Thomas Browne,* Vol. 4, 320.
[741] Browne, *The Works of Sir Thomas Browne,* Vol. 4, 320.

That Dugdale is bothered by what his own and others' observations imply on how much time is needed for these natural events to occur is clear, because even without the 'light of History or Records' to guide him, he nevertheless declares in his published account that it would take not a few, but several 'Ages' or 'divers hundreds of years' to cause the 'depth of the Moor' to 'grow to that thicknesse'. Yet this estimate of time is carefully vague enough that it fits within the limits of the Mosaic timescale, which becomes important in a later reply from Browne to Dugdale, dated 'Oct. 1660', when their discourse takes a fossil turn. 'That petrified bone you sent me,' Browne writes, '[with, which] diverse others, was found underground, neare Cunnington, seems to be the vertebra, spondyle, or rackbone of some large fish'.[742] But he highlights the problem, similarly to Ray, that 'We are not readie to believe that wherever such reliques of fish or sea animals are found, the sea hath had its course'. Browne reasons that since 'many [shells] may be brought unto places where they were not first found' – later, Plot's argument – it 'may deceive some … that the sea hath come so high'.[743] Unlike Plot, however, who uses this argument to support the *lapides sui generis* opinion, Browne points to the possibility that some shells were simply leftovers discarded inland by humans, not as a way to refute the organic origin of fossils, but to remind Dugdale that each layer of earth is compacted with civil history and natural history, which are sometimes indistinguishable.

Reminiscing five years back about 'an humerous man of this countrie', who 'after his death and according to his own desire, was wrap't up in the horned hide of an oxe, and so buried', Browne tells a cautionary tale on how the loss of a memory of an event can 'confound … discoverers'. When 'the memorie hereof is past,' when the man and his idiosyncratic 'desire' are forgotten like so much history in time, 'how this may heereafter counfound the discoverers, and what conjectures may arise thereof, it is not easie to conjecture'. For this reason, 'manie things prove obscure in subterraneous

742 Browne, *The Works of Sir Thomas Browne*, Vol. 4, 323.
743 Browne, *The Works of Sir Thomas Browne*, Vol. 4, 323.

discoverie'.[744] (This could easily serve as a poetic remark on history in general.) Nevertheless, Browne admits that he has 'elsewhere declared' (in his *Urn Burial* of 1658) that the

> greatest antiquities of mortall bodies may remaine in petrified bones, whereof some may be older then the pyramides in the petrified reliques of the generall Inundation.[745]

Again, that 'petrified bones' are 'reliques of the generall Inundation' was a convention that Steno adhered to, and Hooke defied. To fortify the claim in his reply to Dugdale, Browne relies on a reference that Hooke would dust off in his own defence: that 'Herodotus and Plutarch thought it noe small argument, from multitude of severall shells found upon the higher ground of AEgypt to inferr that those parts had beene sometimes underwater'.[746] Yet despite Dugdale and Browne's discourse on fossils, because Dugdale 'can say nothing' on the timescale, what 'puzles' him most is how (not when) the sea 'much altered its course as to the height of its fluxes and refluxes'.[747]

> Since I wrote to you for your opinion touching the various course of the Sea, I met [with] some notable instances of that kinde in a late Author, vzt Olivarius Uredius, in his Hist: of Flanders [which] he manifesteth to be occasioned from Earthquakes.[748]

Dugdale is seriously considering the possibility that the land was altered by what would a few years later become Hooke's main mechanism: earthquakes. More important, he publishes it as the conclusive explanation in his *History of Imbanking and Drayning*.

In Chapter 33 ('How it became overflowed by the Sea'), forming relations between the bits of evidence discussed with Browne, Dugdale claims he can

[744] Browne, *The Works of Sir Thomas Browne*, Vol. 4, 324–325.
[745] Browne, *The Works of Sir Thomas Browne*, Vol. 4, 324.
[746] Browne, *The Works of Sir Thomas Browne*, Vol. 4, 342
[747] William Dugdale, in Thomas Browne, and Geoffrey Keynes (ed), *The Works of Sir Thomas Browne*, Vol. 4, 316, 318.
[748] Dugdale, in Browne, and Keynes (ed), *The Works of Sir Thomas Browne*, Vol. 4, 322. See also Parry, 'Thomas Browne and the Uses of Antiquity', 75. Browne's reply, to the best of my current knowledge, is extinct.

> demonstrate by what means it came to passe, that the Ocean, at first, brake into it [England] with such violence, as that the woods then standing throughout the same, became turned up by the roots[.][749]

Further, how 'so great a proportion of silt [was] brought in', which 'did cover the ground to an extraordinary depth' for 'divers miles' – indeed, 'even to the remotest parts on the verge of the High Lands'. Like Hooke, Dugdale relies on the Cunnington fish fossil and an argument from similitude for his demonstration. That the ocean breaking violently into the land was an actual event is 'apparent from' the appearance and shape of the fish fossil, found 'lying in perfect silt, [more than] six foot below the superficies of the ground'. That it was once a 'large Sea-fish', which 'by so long a continuance in that kind of [fenny] earth, was petrified' is, according to Dugdale, 'evident from divers of the bones, both of the back and other parts'.[750] Unlike Hooke, Dugdale neither attempts to convince his readers that the fossil was once a fish with experimental evidence, nor to generalise from the particular; his concern is the Fens and their local history. Finally, making a move from several past instances of earthquakes and flooding to the case of the Fens, Dugdale claims that, from the 'unquestionable testimony' of Ovid, and other ancient historians, which supports the claim 'that such dreadful accidents have occasioned the like', the 'violent breach and inundation of the Sea' was caused by 'some great Earthquake'. Indeed, he cites the passage on mountaintops where shells and 'old Anchors have beene found' from the *Metamorphoses* that Hooke would also highlight (Chapter 5).[751] From Dugdale's "demonstration", one can infer that his stance on fossils reflects his pro-drainage Fens agenda, or the dynamic view of nature that he upholds. However, Dugdale again refuses to speculate on *when* such an earthquake may have happened: 'But when and by what means that violent breach and inundation of the Sea was first made in this Country, I am not able positively to

[749] Dugdale, *History of Imbanking and Drayning*, 172.
[750] Dugdale, *History of Imbanking and Drayning*, 172.
[751] Dugdale, *History of Imbanking and Drayning*, 172–173.

affirm'.[752] For him, coupling fossilised fish bones with the 'unquestionable testimony' of historical records, which provide 'the most rational probabilities' that it was an earthquake, is sufficient proof.[753]

As shown in Chapter 2, Hooke had similar ideas to Dugdale that he put into practice shortly afterwards when investigating rotten oaks and petrified firs in the *Micrographia*:

> all that I have yet seen, seem to have been rotten Wood before the petrifaction was begun; and not long since, examining and viewing a huge great *Oak*, that seem'd with meer age to be rotten as it stood, I was very much confirm'd in this opinion[.][754]

Yet, as Hooke further explains, all woods must rot before beginning to petrify; the oaks and firs described by Dugdale were rotten, but not petrified. This distinction defines what bothers both and each of them. Hooke needs to convince his audience that fossils were once living things, and that earthquakes are *the* mechanism for explaining what Gal termed 'discrepancies of substance and place'.[755] As examined earlier with the visual pair of the "characteristic marks" of charcoal versus the petrified wood pores of a piece of *lignum fossile*, Hooke first has to create these marks with observations, experiments, visual thinking and illustrations before teaching everyone how to "read" them. Ideally, unlike Dugdale's "unquestionable testimonies", Hooke's should come from the "witnesses" of his often experiment- and instrument-mediated observations. These experimental observations are designed to show not only that petrified wood was once rotten and before that living, but that the variety of *all* petrified bodies dug up in diverse parts of the world are 'a single phenomenon'.[756]

In the *Discourse of Earthquakes*, Hooke introduces 'two other Causes of the mutation of the superficial Parts of the Earth' (the first, of course, being

[752] Dugdale, *History of Imbanking and Drayning*, 172.
[753] Dugdale, *History of Imbanking and Drayning*, 172.
[754] Hooke, *Micrographia*, 107.
[755] Gal, 'Nature's Grammar', 502.
[756] Gal, 'Nature's Grammar', 502.

earthquakes), namely, 'the Sea's overflowing of a Country or Place, when forced on it with some violent Storms or Hurricanes' and 'the over-flowing of Rivers from great falls of Rain, or from something stopping their Course'. For the latter, Hooke mentions some effects of the Thames bursting its banks in London and flooding the streets and cellars, and lists several instances of subterraneous trees, as a sort of transition to the expansion of his observations and experiments on the *lignum fossile*. For instance, Hooke describes reading accounts by 'Childery' and 'Cambden' that describe a similar scene to Dugdale's subterraneous trees. In a moor at '*Chatmoss* in *Lankashire*', trees that 'some think … to be Fir-Trees', whose roots were loosened by the boggy ground, were found 'so sunk into that soft Earth' that they had been 'swallowed up' whole.[757] It is probable that Hooke accumulated some practical knowledge from the Royal Society reading of Dugdale's book (if no other way), but he shares none of Dugdale's qualms or reservations regarding there being no 'memorial thereof transmitted to us, from the light of History or Records'.[758] Rather, Hooke, the oxymoronic "natural antiquary", extracts the history of the earth's changes from civil histories and myths, and examines oaks, firs and other woods as historical 'Records'. And here again is the transfer of value from the pristine and divine to earthy matter and what Burnet and others called "rubbish". When the 'History or Records' of nature fail to cohere with civil or sacred histories, Hooke relies on nature's trustworthy and thus more valuable antiquities, because nature, unlike human art, does not fabricate counterfeits or play games – there are no *lusus naturae*.[759]

### 8.4 'Of the Moon'

[757] Hooke, *Discourse of Earthquakes*, 314.

[758] Although Hooke and Dugdale may have never met face to face, Hooke was present during the reading of Dugdale's *History of Drayning and Embanking*, and owned a copy of Dugdale's *History of Saint Paul's Cathedral of London with Figures* (London, 1658); for the latter, see: Felicity Henderson, Yelda Nasifoglue and Will Poole (eds), 'Hooke's Books Database | Robert Hooke's Books', hookesbooks.com, 2018, <http://www.hookesbooks.com/hookes-books-database/>.

[759] For the latter, also see Rhoda Rappaport, 'Hooke on Earthquakes: Lectures, Strategy, and Audience' (*The British Journal for the History of Science*, Vol. 19, No. 2, July 1986, 129–146 ), 140–141.

Hence there are no *lapides sui generis*. On the organic origins side of the controversy, this conclusion enabled natural philosophers like Hooke and Steno to begin thinking about and attempting to establish a '*historical* investigation of nature'.[760] Coming to terms with and accepting a natural history with a past as deep as a yawning abyss was connected to embracing the concept and problem of a metamorphosing Earth, since to allow for such natural changes, a longer amount of time would have to be admitted. Yet, as shown, subjecting history to the investigative procedures of the new science by using fossils as instruments did not also mean contradicting the six-thousand-year Mosaic period – though Hooke and others would press against this constraint. Most natural philosophers, even those who shared and, for the most part, supported Hooke's doctrine, were not willing to pay the intellectual price of living in a present far removed from the beginning, and of sacrificing a sacred historical record of an actual event for the creation of a fragmented natural history.[761] Their insistence on agreeing about the necessity of Noah's flood was a compromise that subdued some of the above anxieties and quarrels by making fossils part of sacred history. But agreeing on the flood still left much concerning the new history of nature to disagree on, and Hooke's idiosyncratic and defiant dismissal of it underscores that even this compromise was not absolute. Amongst the proponents of the organic opinion, Hooke alone, with a discourse of earthquakes – not deluges – rejected Noah's flood as the causal agent for fossils, arguing instead that earthquakes and other subterraneous eruptions can also be observed to have occurred on the moon.

### 8.4.1 'UNIVERSALITY'

In his first exegesis of *Genesis*, during a 1668 *Discourse* lecture, Hooke postulates that the separation of water and land was caused by an 'extraordinary

[760] Rossi, *The Dark Abyss of Time*, viii–ix.

[761] As explained by Oldroyd, the flood story formed a crucial part of the early history of geology, up to the nineteenth century, because of the belief that it was an actual historical event as well as a moral lesson: Oldroyd, *Thinking about the earth*, 14.

Earthquake'.[762] Indeed, for him, earthquakes are the primary mechanism for dislocation and transportation of fossils found embedded in strata, and possess a 'universality' that floods lack:

> There is only one thing more that I think pertinent to our present purpose, and that is the universality of this active Principle: There is no Country almost in the World but has been sometimes or other shaken by Earthquakes[.][763]

Not only this, but three years before in the *Micrographia*, Hooke had already attempted to persuade his readers that the 'universality of this active Principle', or first cause, was not bound by terrestrial constraints, when describing an observation of what he speculated were the surface effects of subterraneous eruptions on the moon. Hooke has no qualms over blurring the epistemological boundaries of the terrestrial and celestial realms when it comes to moving his notions on earthquakes and eruptions from the relatively local environment of the earth to other planets and vice versa. In 'Observ. LX. *Of the* Moon', he swaps his microscopes for a telescope to provide a '*Specimen'* of the moon's surface, 'a very spacious Vale', drawn 'by a thirty foot Glass, in *October* 1664', just before it was half-lit – lighting that accentuates surface elevations and depressions.

As mentioned, Hooke borrows a trope invented by Galileo, in the latter's *Sidereus Nuncius* (1610), for his description of the moon's surface appearance: Galileo's description of a maculate moon, which had by Hooke's time become a commonplace idiom.[764] So, while Hooke notes that 'from several appearances of it', the vale 'may have Vegetables *analogus* to our Grass, Shrubs, and Trees', he makes his observations on 'Vegetables' only in passing to his primary interest: the 'several kinds of pits'.[765] Hooke imagines that these

762 Hooke, *Discourse of Earthquakes*, 314.
763 Hooke, *Discourse of Earthquakes*, 311.
764 Hodoba Eric, *The Capture of Spring*, 70–71.
765 Hooke, *Micrographia*, 242–243. Also see Hooke, *The Diary of Robert Hooke*, 214: 'I told them how strangely deer it represented All the parts of the Moon both those of the limb and those of the middle parts at all times and even in a full Moon Distinct. I argued for water in the Moon and that the under parts of the sea were seen as well as the tops of hills. and alledged my experience of seeing the bottom of the sea from the top of a high Clif that could not be seen at the top of the water. Sir Christopher affirmd noe water nor River nor cloudes. mountains not like ours nor vales. (Q: whether the water hath not wholly covrd the face of our Earth and

pits are the effects of 'some motions within the body of the Moon, *analogus* to our Earthquakes':

> divers places resembling some of these [pits], I have observed here in *England*, on the tops of some Hills, which might have been caus'd by some Earthquake in the younger dayes of the world.[766]

The 'younger dayes', that is, when the world was a little less decayed and ruined. That 'which does most incline me to this belief,' Hooke tells his readers, is 'first, the generality and diversity' of pits on the moon. 'Next, the two experimental ways, by which I have made a representation of them'. That is, observations confirmed by experiments. Although Hooke provides accounts of two experiments, which examine external versus internal potential causes of pits respectively, he has already decided on the latter, which supports what he presents as his earthquakes 'Doctrine' three years later.

> The first [experiment] was with a very soft and well temper'd mixture of Tobacco-pipe clay and Water, into which, if I let fall any heavy body, as a Bullet, it would throw up the mixture round the place, which for a while would make a representation, not unlike these of the Moon[.][767]

That is, the first experiment 'would make a representation' of craters caused by a 'heavy body' striking the moon's surface. Scholars in the past have drawn anachronistic attention to this experiment while ignoring the second one.[768] Yet Hooke rejects it as the less probable hypothesis, for 'considering the state and condition of the moon … it would be difficult to imagine whence those [striking] bodies should come'. The second experiment, 'and most notable, representation was, what I observ'd in a pot of boyling Alabaster,'

> for there that powder being *by the eruption of vapours* reduc'd to a kind of fluid consistence … *the whole surface*, especially that where some of the last Bubbles have risen, *will appear all over covered with small pits, exactly*

whether it doth not wast by passing the ether.)'.

766 Hooke, *Micrographia*, 243.

767 Hooke, *Micrographia*, 243.

768 For example, watch Allan Chapman, *Robert Hooke's models of the moon*, in Patrick Moore, *The Sky at Night: Mapping the Moon* (BBC Four, 15 February 2010), at https://www.bbc.co.uk/programmes/p006glrx. Re-accessed 22/12/22.

> *shap'd like these of the Moon,* and by holding a lighted Candle … in divers positions to this surface, you may exactly represent all the *Phenomena* of these pits in the Moon, according as they are more or less inlightned by the Sun.[769]

Hooke's argument by analogy allows him to form a successful visual triptych between his moon drawing, his chosen experimental 'representation', and the earth's surface. The actual moon itself is no longer a necessary part of the argument. His descriptions of the boiling alabaster animate the eight pits in his moon drawing of the vale, forming the first part of the triptych. Next, Hooke uses observations of the earth's surface to support his claims:

> that there may have been in the Moon some such motion as this, which may have made these pits, will seem the more probable, if we suppose it like our Earth, for the Earthquakes here with us seem to proceed from some such cause, as the boyling of the pot of Alabaster[.][770]

He provides a commonplace list for how these motions may be 'generated' in the earth, including 'subterraneous fires, heat, great quantities of vapours'. Expanding on vapours, which he prefers on account of their elasticity, he explains that subterraneous fires cause 'aerial substances' trapped in the earth to rarefy, but since they have 'not sufficient room to expand themselves', upon becoming 'extremely condens'd', the vapours 'at last overpower, with their *elastick* properties, the resistance', thus 'lifting … cleaving … and so shattering of the parts of the Earth'. Further, these expelling vapours 'not only raise a small brim round about the place, out of which they break, but for the most part considerable high Hills and Mountains'. For example, when these vapours break out of the earth 'under the Sea', they often raise 'mountainous Islands; this seems confirm'd by the *Vulcans* in several places of the Earth,'[771]

> the mouths of which, for the most part, are incompassed with a Hill of considerable height, and the tops of those Hills, or Mountains, are usually

769 Hooke, *Micrographia*, 243. Italics added.
770 Hooke, *Micrographia*, 243–244.
771 Hooke, *Micrographia*, 244.

> shap'd very much like these pits, or dishes, of the Moon … *Aetna* in *Sicily* … *Hecla* in *Iceland* … *Tenerif* in the *Canaries* …[772]

In forming a relation between earthquakes and the second experiment, Hooke completes the triptych of the moon drawing, the experimental 'representation' of boiling alabaster, and the earth's superficies. The paradox of making an experimental representation of subterraneous motions in the moon to discuss *earth*quakes was pointed out by Davies when concluding that Hooke's 'experiments on selenomorphology must – paradoxically – entitle [him] to be hailed as our first experimental geomorphologist'.[773]

To strengthen the relations holding the triptych together, Hooke provides three reasons for the probability of his "internal motions" hypothesis of the second experiment. First, 'it is not improbable that the substance of the Moon may be very much like that of our Earth'. Second, the moon, like the sun, probably has 'divers such kind of internal fires and heats, as may produce such Exhalations'; and since the sun is 'accounted the most noble AEthereal body, certainly we need not be much scandaliz'd at such kind of alterations, or corruptions, in the body of this lower and less considerable part of the universe, the Moon'.[774] Implicit here is that one should not be scandalised that the earth also has such 'alterations, or corruptions'. Third, and perhaps surprising, if one supposes 'a sandy or mouldring substance to be found' on the moon as well as 'a possibility of the generation of the internal *elastical* body (whether you call it air or vapours)', then one can infer 'that there is in the Moon a principle of gravitation, such as in the Earth'.[775]

Anyway, in the *Discourse*, Hooke further diminishes the significance of floods, and in particular Noah's, which is limited to the earth, by attempting to show first with an argument from history or 'Heathen Writers' that there have been other floods like it, that is, producing similar effects upon the earth's superficies. Second, like Dugdale, Hooke argues that earthquakes *cause*

772 Hooke, *Micrographia*, 244.
773 Davies, *The Earth in Decay*, 72.
774 Hooke, *Micrographia*, 244.
775 Hooke, *Micrographia*, 245.

floods, which then also contribute to transporting objects such as 'Shells' by a 'washing of Waters in motion'.[776] So it comes as no surprise when he speculates that an earthquake caused Noah's flood. If 'Earthquakes can raise the Surface of the Earth in one place and sink it in another', then another earthquake could 'on the contrary level those Mountains again, and fill those Pits, and reduce the Body of the Earth to its primitive roundness' (importantly like the shape of other planets); 'and then the Waters must necessarily cover all the Face of the Earth as well as it did in the beginning of the World …' Thus, deliberately reversing the separation of the water from the land, Hooke claims

> 'tis not improbable but in the Flood of Noah, the Omnipotent might make use of this means [earthquakes] to produce that great effect [floods] which destroyed all Flesh, and every living thing, save what was saved alive in the Ark.[777]

In 1690, he would expound upon this reversal or un-creation, followed by re-creation, of the earth. Hooke claims 'whether the dry Land that appeared after the Flood, were the same with that before the Flood, is a question not easily determinable'. But, 'to me it seems that the preceding Earth was wholly changed and destroyed, and that there was produced a new Earth which before that had not appeared'.[778] Recall, Hooke dismisses as 'improbable' Plot and Lister's hypothesis that 'other Mens Hands' were responsible for the transport of fossils found out of place, and also rejects 'the general Deluge' because it 'lasted but a little while'.[779] In a slightly earlier lecture, he argues

[776] Hooke, *Discourse of Earthquakes*, 314.

[777] Rappaport, in 'Hooke on Earthquakes: Lectures, Strategy, and Audience', argued that Hooke's exegesis of Noah's flood is inconsistent because of his attempt, in much later *Discourse* lectures, 'to alter his own earlier [1668] interpretation of that text [*Genesis*]' to conclude that 'the Flood had been essentially a great earthquake' (139). Rappaport noted that in a 1693 lecture, Hooke 'gave up his effort to reinterpret the Flood [as an earthquake] which once more became simply a brief "soaking of the Earth"' (140). However, in Hooke, *Discourse of Earthquakes,* the actual citation is 'Certainly a twelve Month soaking of the Earth, much less forty Days, could not reduce the superficial Parts to such a hasty pudding Consistence as this Phaenomenon [fossils embedded in strata] does seem to require' (440); there is no contradiction between this statement and Hooke's earlier claims. Moreover, there is a difference between stating that the flood was an earthquake and that it was caused by one; Hooke never makes the former claim.

[778] Hooke, *Discourse of Earthquakes*, 422.

[779] Hooke, *Discourse of Earthquakes*, 320.

that since 'the duration' of the deluge 'was but about two hundred Natural Days, or half an Year' (summing forty days and forty nights of rain and 150 in which "the water prevailed upon the earth"), it 'could not afford time enough for the production and perfection of so many and so great and full grown Shells, as these which are so found do testify'. Moreover, 'the quantity and thickness of the Beds of Sand with which they are many times found mixed, do argue that there must needs be a much longer time of the Seas Residence above the same, than so short a space can afford'.[780] This, then, is a rejection of the flood not only as a transport mechanism but also of fossil creation.[781]

The following year, in another exegesis of *Genesis*, Hooke would attempt to use interpretations made by the 'Commentators' of 'Holy Writ' against them. If 'the time' that the earth has spent completely submerged under water after Creation is 'no longer than the duration of the Flood', and if we suppose that the surface remained unchanged after it, then 'that space of time will not be found of duration long enough to produce *de novo* such multitudes of those Creatures'. Nor can Hooke imagine how marine life that does not swim, but adheres to rock and so on, can be transported 'to the top of the Mountains' and other places remote from its origin. Again, when it comes to choosing between sacred, or civil, history and nature's records, Hooke relies on the testimonies provided by the "marks and tokens" of fossils, which show that the only way Noah's flood could have played a role in fossil transportation is if a great earthquake catastrophically changed the earth's surface at that time.[782] In this respect, Hooke and Steno agree that the earth had a new face after the flood. But only Hooke – neither Steno nor anyone else we have examined – suggests that similar earthquakes and floods had happened before and would happen again. For him, there is nothing special about Noah's flood where fossils are concerned: 'those universal *Phaenomena* of the remainders of the Sea which are found in all parts almost of the present superficial Parts of the Earth, could not be caused by the general Flood of

[780] Hooke, *Discourse of Earthquakes*, 341.
[781] Hooke, *Discourse of Earthquakes*, 341.
[782] Hooke, *Discourse of Earthquakes*, 412.

*Noah*' unless the flood itself was the effect of an earthquake.[783] In his final *Discourse* lecture, given three years before his death, Hooke takes a swipe at the likes of Steno, Ray and Woodward with the statement that ''tis usual for most' to attribute fossils to Noah's flood 'where they can think of no other Cause'.[784]

### 8.4.2 'THOSE UNIVERSAL *PHAENOMENA*'

> I have formerly endeavour'd to explain several Observations I had made concerning the Figure, Form, Position, Distance, Order, Motions and Operations of the Celestial Bodies, both as to themselves, and one with another.[785]

This is the opening sentence of Hooke's *Discourse of Earthquakes*. Following it, Hooke forms a relation between 'Celestial Bodies' in general and a singular celestial body by explaining that 'it may more nearly concern us to know more particularly the Constitution; Figure, Magnitude and Properties of the Body of the *Earth* itself, and of its several constituent Parts'. By 'the Body', Hooke means the usual 'whole Bulk included within the utmost limits of the Atmosphere'.[786] In light of Hooke's *Micrographia* observation that the moon is analogous to the earth, it makes epistemological sense that studying the former should yield more intimate knowledge on the matter and operations of other primary and secondary planets.[787] Hooke argues that if one could observe the earth from the moon, its shape and dynamic surface – with seas and vegetation and so on – would look like the moon's, since the pair also share both a principle of gravitation accounting for globularity, and the same cause of internal motions, which produce surface effects like those in the afore-described pot of boiling alabaster. Hooke's concern here, however, is not the earth's planetary motions, but its internal ones, and his ideas and inversion of values (his

783 Hooke, *Discourse of Earthquakes*, 412.
784 Hooke, *Discourse of Earthquakes*, 436.
785 Hooke, *Discourse of Earthquakes*, 279.
786 Hooke, *Discourse of Earthquakes*, 279.
787 Hooke, *Micrographia*, Observ. LX. *Of the Moon.*

preference for the common over the rare) bear greater similarity to several propositions on the moon put forward by his mentor John Wilkins. For example, Wilkins postulated that '*the Heavens do not consist of any such pure Matter, which can privilege them from the like Change and Corruption as these Inferior Bodies are liable unto*', lowering their status as Hooke would to senescing bodies, and 'That as their [the moon's inhabitants'] World is our Moon, so our World is their Moon'.[788] Moreover, Hooke's agenda here is not to support Copernicus's claim that the earth moves, but his own 'Doctrine': that the earth is also subjected to local physical changes.

Adding to the above discourses, Hooke claims that 'there is in the Moon a principle of gravitation such as in the Earth', and one needs 'no better Argument, then the roundness, or globular Figure of the body of the Moon it self'; the cause of 'gravitation' cannot be from a 'turbinated' or 'diurnal motion' like the earth's since 'the Moon is not mov'd about its Center', thus gravity in general does not depend on any planet's diurnal motion. That is, gravity is not caused by the earth revolving on its axis, since the moon, which also has gravity, does not rotate. Moreover, if the moon's 'mouldring substance', which is similar to the earth's, had no gravitating principle to firmly contain all its parts by pulling them towards a common centre, then its internal motions would break the planet to pieces instead of causing pits on the superficies.[789] But Hooke observes the opposite effect both on the earth and the moon. When viewed with 'an excellent *Telescope*', the 'mountainous or prominent parts' of the moon resemble their terrestrial counterparts, because both are sculpted by a 'gravitating power':[790] on Earth, the 'parts' of mountainous and hilly regions are 'continually tumbling down from the higher parts to the lower'. The 'very form' of these elevated landforms supports a principle of gravitation, and Hooke takes the opportunity to fire another

[788] Wilkins, *The Discovery of a New World [in the Moon]*, unpaginated (page before page 1). Wilkins was Warden of Wadham College in Oxford. He recruited Hooke into his philosophical club, which, at the start of the 1660s would begin meeting at Gresham College, forming the Royal Society: Allan Chapman, 'Fly Me to the Moon', *Astronomy and Geophysics,* 55, no. 1 (2014): 1.26–1.32, 1.31.
[789] Hooke, Micrographia, 245; Hooke, *Discourse of Earthquakes*, 324.
[790] Hooke, *Micrographia*, 245.

potshot into the *lusus naturae* crowd with the observation that

> some of them do seem to overhang very strangely, which cannot in any probability be imagin'd to be the form of the first Creation, it being contrary to that implanted Power of Gravity.[791]

In this way, fossils are a crucial component of Hooke's explanation not only of eruptions and earthquakes, but also of gravity; and after shifting his audience's focus from celestial bodies to the body of the earth, Hooke further zooms in on the topic of fossils without preamble.[792] To summarise, the moon's shape and surface show that it has a principle of gravitation like the earth's; earthquakes and other subterraneous eruptions change the surface; fossils, in turn, provide evidence that the surface changes, or that it is in motion, over time.

Richard Waller, who scraped together Hooke's *Posthumous Works* from surviving papers, declares, in a brief preface to this first *Discourse* lecture, that he has not had '*the happiness to meet with*' these former endeavours on '*Celestial Bodies*' – apart from some '*Hints*' in the later '*Lectures of Light, and at the end of his [Hooke's] "Tract of Comets"*'.[793] However, one can infer that Hooke is referring to his 1666 '*Address* to the Royal Society' on orbits as effects of 'the inflection of a direct motion into a curve by a supervening attractive principle';[794] and certainly to his final *Micrographia* observations and experiments in 'Observ. LX. *Of the* Moon', recycling them towards the end of this first *Discourse* lecture.[795] In this lecture, Hooke picks up where he left off in '*Of the* Moon', turning his 'Hints' into the last part of an argument supporting the sixth proposition that 'the greatest part of the inequality' of the earth's

791 Hooke, *Discourse of Earthquakes*, 324.
792 Hooke, *Discourse of Earthquakes*, 279.
793 Richard Waller, in Robert Hooke, and Richard Waller (ed), *The Posthumous Works* (London: Sam Smith and Benjamin Walford, 1705), 279.
794 Hooke, *Micrographia*, 217. According to Hooke, the earth's atmosphere is a heterogeneous fluid enveloping the earth. However, he takes pains to point out that it is not like Kepler's conception of a spherical atmosphere – that is, a fluid with an interface between aether and heterogeneous air which accounts for refraction – because although air rarefies the further it is from Earth, it is 'indefinitely extended upwards': Hooke, *Micrographia*, 227, 239–240. For Kepler, see also Kepler, *Optics*, 281–292.
795 Birch, *The History of the Royal Society of London*, Vol. 1, 90, 92; Hooke and Gunther (ed), *Early Science in Oxford*, Vol. 6, 265, 267.

surface was caused by 'the subversions and overturnings of some preceding Earthquakes'.[796] First, upon employing his fossil synecdoche (examined earlier) to argue that the strata and extinct 'Vulcans' provide evidence that the earth is undergoing petrifaction, that is, all solids were once liquids, Hooke hypothesises that without earthquakes, the earth would still be in a pre-Creation state (in coherence with his claim that the separation of land and waters in *Genesis* was the effect of an earthquake). If, as mentioned, the 'Principle of Gravity' compresses the earth's 'Parts … as near to an exact spherical Figure as their Solidity and forc'd Postures will permit', then the 'natural form produc'd by Gravity would be a multitude of Spherical Shells concreted of the several Substances of which it consists'.[797] Providing common visuals to assist the imagination in world-making, Hooke explains that this globular earth would be 'not unlike the Orbits or Shells … of an Onion, or as the *Ptolemaiick* Astronomers do fancy the solid Orbs of the Heavens'.[798] That is, because of the effect of the force of gravity, and because of the different density of the homogenous matter of each concentric orb, 'that which hath been heaviest would have approach'd nearest the Center, or at least nearest to that part which is attractive and the cause of Gravitation, if such a Body there be in the middle of the Earth'. In this pre-Creation design, 'Water would always have covered the Face of the Earth, and the lightest Liquor would always have been at the top, and the Air above that' and so on. But because the earth has been 'disturbed by Earthquakes' and volcanic eruptions and so on, Hooke argues that these orbs were broken and churned time and again, which he reckons is 'the reason of the scarcity of those heavy Bodies of Metal near the Surface', such as gold.[799] Again, fossils, 'those universal *Phaenomena*', are traces of the earth's past in motion: they attain their universality from being dislocated, transported and buried by earthquakes.

Next, in a reversal of his introduction, where he re-directed the topic from

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[796] Hooke, *Discourse of Earthquakes*, 219 [sixth proposition], 317–328 [the last argument, which consists of ten 'proofs', for the sixth proposition], 325.
[797] Hooke, *Discourse of Earthquakes*, 325.
[798] Hooke, *Discourse of Earthquakes*, 325, 326.
[799] Hooke, *Discourse of Earthquakes*, 326.

celestial bodies to the earth, nearing the conclusion of this first *Discourse* lecture, Hooke shifts the frame of reference from the earth back to planets in general by re-using his observations and experiments from the *Micrographia*'s close. 'There is yet one Argument more that to me seems very good, and that is fetcht from no less distance than the Moon and the Sun by the help of Telescopes'.[800] This move opens a way for Hooke to further support his claims on the universality of not only gravity, hinted at in the *Micrographia* and developed a notch in 1666, but also earthquakes. If there is no superficial part of Earth that has not been affected by earthquakes, and if the moon and even the Sun have 'divers such kind of internal fires and heats, as may produce such Exhalations', then why not other planets. Indeed, on account of their roles in the physical formation and shaping of a planet, the two "universal principles" become entangled in Hooke's argument:

> These Bodies, as I have formerly hinted in the latter end of my *Micrography*, seem to have the same Principle of Gravity as the Earth, which seems probable from their Spherical Figure in general, and the several inequalities in particular … on the Surface of the Moon, and the several Smoaks, and Clouds, and Spots that appear on the Surface of the Sun[.][801]

What began as a broad relation between other celestial bodies and the earth in Hooke's introduction, in the conclusion becomes a more refined relationship between general globularity (an effect of gravity) or equalities, and the particular 'inequalities' observed on the sun and Moon (effects of earthquakes, active volcanoes and the atmosphere), which represent the earth's surface in general, since 'as they have that Principle in common with the Earth, so it seems to me that they are not free from the like motions with those of an Earthquake'. It is this latter 'Principle' that Hooke's boiling alabaster experiment mimics. Hooke recycles and brings the experiment to the fore in an attempt to generate both ontological and epistemological certainty with an argument from similitude constructed of three cause-effect correspondences

[800] Hooke, *Discourse of Earthquakes*, 326.
[801] Hooke, *Discourse of Earthquakes*, 327.

that together deliberately conflate nature and art:

> all those Pits in the Moon being much like the Caldera or Vent at the top of Vulcans here on the Earth, or like those little Pits left at the top of surface of the Alabaster Dust *by the natural subsiding of that Dust* in the place where the Vapours generated within the Body of it break out.[802]

Although Hooke generates a similar effect artificially, the 'Dust' settles naturally into the appearance of a moon pit or volcano 'Vent'; this outcome erases the difference between art and nature. The boiling alabaster experiment is one more example of a practical-theoretical tool that Hooke uses to re-imagine nature's history.

In Hooke's new history, fossils, which acquire the description of 'universal Phaenomena' from the actions of the two universal principles, gravity and earthquakes, 'are no less capable of Proof and Confirmation, than Histories or Records are by Coins, Inscriptions or Monuments'. Fossils embed and trace these histories in their very substances and dislocations, as they petrify like the earth and other planets. At the end of his last *Discourse* lecture, Hooke reiterates that 'this Assertion of the growing old of the Earth' is not 'so great a Paradox, or Heterodoxical, or Scismatical'. Using the Scriptures in support of natural philosophy again, rather than the other way around, Hooke argues that 'the Kingly Prophet David in the 102 Psalm has an Expression that doth plainly assert it, not only of the Earth but even of the Heaven':[803]

> Of old hast thou laid the foundations of the Earth, and the Heavens are the works of thy hands, they shall perish, but thou shalt indure; yea all of them shall wax old like a garment, as a vesture shalt thou change them, and they shall be changed.[804]

To Hooke, it is ridiculous that amidst so much motion one should continue to argue that the earth's superficies and its parts are static.

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[802] Hooke, *Discourse of Earthquakes*, 327–328. Italics added.
[803] Hooke, *Discourse of Earthquakes*, 427.
[804] Hooke, *Discourse of Earthquakes*, 427.

# Chapter 9: Protogaea

There are no *lusus naturae*, so there are no *lapides sui generis*. Sometime before penning the *Protogaea*, Gottfried Wilhelm Leibniz (1646–1716), who had initially defended the *lusus naturae* idea, changed his mind. As put by Claudine Cohen and Andre Wakefield, Leibniz had gained a 'new "historical" perspective' and thus 'broke with the approach inspired by the hermetic and symbolist tradition'.[805] In an undated manuscript, Leibniz had found the hypothesis that fossils are the remains of once living animals and plants 'hard to believe' because 'If this is so, the earth must be much older than the Bible indicates'. Concerned with defending the biblical timescale then, Leibniz took Athanasius Kircher on authority, declaring it a 'fact that stones grow and take on many odd shapes; for proof of this we have only to look at the stones that R.P. Kircher accumulated in his Subterraneous World'. Thus, 'What I believe is that these shapes of animals and shells … were created independently and have no relation to animals'.[806] However, in the *Protogaea*, Leibniz not only eats his words but strikes against Kircher, Johann Becher, and their followers (his former self included):

> Whoever believes the contrary is seduced by the fairy tales of Kircher and Becher, and other credulous vain writers of this sort, who describe the wonderful games of nature and its formative power, all embellished with a great display of words.[807]

The *Protogaea* relies not on 'a great display of words' but on practical knowledge – or what Bacon termed 'experimental histories' (see 8.1) – as well

805 Claudine Cohen and Andre Wakefield, *Introduction*, in Gottfried Wilhelm Leibniz, and Claudine Cohen and Andre Wakefield (eds and trans), *Protogaea* (London, UK: University of Chicago Press, 2008 [1749]), xxvi.

806 Gottfried Wilhelm Leibniz, LH XXXVII, 4, 16r, cited in Leibniz, Cohen and Wakefield (eds), *Protogaea*, xxvi–xxvii. In fact, Claudine Cohen discovered the manuscript, which must have been incredibly exciting, and for her study of it, see Claudine Cohen, 'An Unpublished Manuscript of Leibniz (1646–1716) on the Nature of "Fossil Objects"', Bulletin de la Société Géologique de France 169, no. 1 (1998): 137–42.

807 Leibniz, *Protogaea*, 73.

as familial and civil history to argue, like Hooke and Steno, that fossils are nature's historical texts. Before, Leibniz had tried to show 'by means of a rational process'[808] that fossils are a product of nature's games; but in the *Protogaea* he argues that careful observation, artisanal techniques and experimental procedures reveal fossils to be either petrified plants and animals or their imprints. Whatever the cause of the about-turn in his understanding and visuality – maybe his meeting Steno, in either 1677 or 1678 in Hannover, since recall that Steno was also critical of Kircher's use of correspondences for fossils – in the *Protogaea*, Leibniz claims that what *lusus naturae* believers

> see in stones are not so much animals, plants, and parts of these, but fables, stories, and myths, such as Christ and Moses on the walls of the Baumann Cave; Apollo with the muses in the agate of Pyrrhus; the pope and Luther in the stone of Eisleben; and the sun, moon, and stars in marble.[809]

The imagination must be primed or 'forewarned' to "see" these images in stones:

> I consider these to be games *not* of nature, but of the human imagination, which sees battles in the clouds and hears its favourite melodies in the sound of bells or the beating of drums … stone figures that you would not recognise unless you were forewarned.[810]

According to Leibniz, such figments are mostly 'fictions or things half seen, and similar to the signatures of things', which he rejects as a lazy way to make claims on what fossils are.[811] As support, he enlists the authority of the 'learned painter' Agostino Scilla, a loud proponent of the organic origins opinion 'who declared in a recently published book that, though he had been shown many such things, the more carefully one observed them, the more tenuous the similarity'. In contrast, 'With true remains … the more carefully and thoroughly one examines them, the clearer are the arguments furnished for their origin'.[812]

808 Leibniz, LH XXXVII, 4, 16r, cited in Leibniz, Cohen and Wakefield (eds), *Protogaea*, xxvi–xxvii.
809 Leibniz, *Protogaea*, 73. Kardel and Maquet, in *Nicolaus Steno,* 3.
810 Leibniz, *Protogaea*, 53. Italics added.
811 Leibniz, *Protogaea*, 75.
812 Leibniz, *Protogaea*, 75. An important difference between Scilla and Leibniz (as well as the other organic origin supporters discussed in *Metamorphoses*) is that Scilla is a bit of an

Thus, by pitting the *Protogaea*, a work of history, against the 'stories' of Kircher, Becher and others, Leibniz portrays the tradition of 'signatures' and correspondences as ahistorical. In this way, perhaps inadvertently, he, like Hooke, follows Bacon's ideas on an alchemy sans traditional signatures.

Employed as the House of Brunswick's advisor, court librarian and historiographer, amongst other duties, Leibniz intended the *Protogaea* to preface a glorious history of the dukedom, the *Origines Guelficae* – allegedly to establish territorial claims.[813] Like Dugdale, whose starting point was also *Genesis* for his history of drainage and the Fens, Leibniz finds it important not to contradict what 'the Bible indicates' when world-making for the purposes of a particular, local present. And since Leibniz had been fooled by the nature's games notion before, perhaps attempting to order the whole of human and sacred history into a chronicle capable of explaining away discrepancies between fossils and their once-living counterparts was doubly important to him. Similarly to Steno's *Prodromus*, which, according to the literature, is Leibniz's most relied-upon textual resource[814] – though Leibniz draws and attempts to synthesise themes from all over, for example, Descartes, Hooke and Ray, Scilla and Burnet – the House's history was left unfinished. The *Protogaea* itself was first published as a synopsis in 1693, and then posthumously edited into a book in 1749 by Christian Ludwig Scheidt, the successor to the post of court historiographer.[815] Scheidt had a cornucopia of

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exception. That is, he styled himself as a painter philosopher, who was proud of his 'painter's eye', to borrow Paula Findlen's lovely description, which 'gave him the kind of probing insight into nature … and the essential skills to transform experience into science through his ability to describe and depict nature *without mediation*' (italics added): Paula Findlen, *Agostino Scilla: A Baroque Painter in Pursuit of Science,* in Ofer Gal and Raz Chen-Morris (eds), *Science in the Age of Baroque* (Dordrecht, The Netherlands: Springer, 2012), 119–159, 122. For an evaluation version of Scilla's English'd work on fossils, see Agostino Scilla, Dan Perberton (ed) and Rosemary Williams (ed and trans), et al., *Vain Speculation Undeceived by Sense* (Cambridge, UK: Sedgwick Museum of Earth Science, University of Cambridge, 2016 [1670]), at http://www.sedgwickmuseum.org/index.php?page=agostino-scilla, re-accessed 22/12/22.

813 Oldroyd, *Thinking about the Earth*, 87. Kardel and Maquet, in *Nicolaus Steno,* 3.

814 Though I rather think it was Ramazzini's *De fontium*: see Hodoba Eric, 'Artificial Apertures: The Archaeology of Ramazzini's *De fontium* in Seventeenth-Century Earth Historiography' (*Centaurus*, Vol. 62, Issue 3, August 2020, 522–541).

815 Oldroyd, *Thinking about the Earth*, 87; Cohen and Wakefield, in Leibniz, *Protogaea*, xxxvii. For a summary of how Scheidt put together the Protogaea, see Justin E H Smith, *Divine Machines:*

Leibniz's manuscripts to choose from, but he favoured the *Protogaea* because providence shines from history, and it was 'proper for the historian' to record 'not only the works of men, but of God'.[816] According to Claudine Cohen and Andre Wakefield, Scheidt found Leibniz's metaphysics unpalatable – nor did he approve of Leibniz's 'conjectural' approach;[817] that is, his treatment of history as hypothetical, an object of scientific investigation. Nevertheless, Scheidt's reason for choosing to publish the *Protogaea* reaffirms its status as a work of history, worthy of a historian's attention, not natural philosophy. But the *Protogaea* transgresses such categorical distinctions by using nature as history, by subjecting history to novel and practical investigative procedures to oppose the *lusus naturae* view that Leibniz formerly supported. Yet for all his criticism of, for example, Kircher's 'stories' and 'fables' about fossils, Leibniz accuses nature, not Man, of deception.

In contrast to Hooke, who, recall, argued that fossils, the 'History or Records' of nature, are more valuable than antiquities and human artefacts as objects of analysis because nature does not play games or make counterfeits, Leibniz claims that 'Nature, instead of humanity, deceives'.[818] He adds that, certainly, 'On the other [human] side, skilled connivers imitate rare mineral forms, like coarse red, vitriform, or fibrous silver, in order to deceive the curious'. A common example of this in Leibniz's time and the historiography is charlatan alchemists alleging to turn base metals into gold; or in the *Protogaea*, 'a clever trick' used by 'travelling merchants' who 'prepare their so-called mandragora from bryony root, so that it forms itself into the shape of a man as it grows'.[819] However, Leibniz concludes that human deceptiveness

*Leibniz and the Sciences of Life* (Princeton and Oxford: Princeton University Press, 2011), 219.

816 Christian Ludwig Scheidt, *Lectori Honoratissimo*, Gottfried Wilhelm Leibniz, and Christian Ludwig Scheidt (ed), Svmmi polyhistoris Godefridi Gvilielmi Leibnitii Protogaea, sive, De prima facie tellvris et antiqvissimae historiae vestigiis in ipsis natvrae monvmentis dissertatio. Svmptibus (Göttingen: Ioh. Gvil. Schmidii, 1749), xiii-xiv: 'Etenim Historicum decet, non hominum tantum, sed DEI opera fideli stilo consignare, immo prouidentiam diuinam, quae non aliunde magis, quam ex historia elucet, quauis data occasione pio celebrare animo.' (At https://wellcomecollection.org/works/g9bt8bgv/items?canvas=1, re-accessed 22/12/22. Transcribed by me.)

817 Cohen and Wakefield, in Leibniz, *Protogaea*, xxxvii.

818 Leibniz, *Protogaea*, 36.

819 Leibniz, *Protogaea*, 75.

is useful: 'They are thus useful in their deception, and teach the art of nature, whose effects they copy'. Once bitten, twice shy, Leibniz's motivation for constructing a history of nature from experimental histories is an outcome of his anxiety over having been deceived previously by nature's art. To avoid a similar deception, Leibniz studies the practices of alchemists, miners, well-diggers, tanners and smiths, as well as the "products common to laboratories and mines" that are like petrifactions: 'I gladly compare the secrets of nature with the visible works of men'.[820] Human arts, crafts and trades 'teach the art of nature'; indeed, the difference between the two arts is only a matter of degree; and by exposing how to copy nature's art, Leibniz replaces history with nature:

> For us, nature thus stands in place of history. But our written history replays nature's grace, so that her brilliant works, which still lie open before us, will not be ignored by posterity.[821]

### 9.1 'Vulcanius Daedalus'

The earth, Leibniz claims, was forged in fire and then 'plunged into water' – as if quenched by a blacksmith or alchemist – both masters of fire. Steams sputtered and hissed around to form the atmosphere as the solidifying globe shrank and its surface shrivelled and cracked, collapsing in parts, from the sudden loss of heat.[822] Borrowing authority from the scriptures, the imagery that Leibniz conjures early in the *Protogaea* is meant to implant the idea of products of nature's art instead of signatures, and is thus a deliberate attempt to start a transformation in his readers' visuality early on:

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820 Leibniz, *Protogaea*, 49.

821 Leibniz, *Protogaea*, 141.

822 Leibniz, *Protogaea*, 15, 9. Although Leibniz refers indirectly to Descartes's *Principles of Philosophy* (IV.2–3), when describing the process of how the matter of the 'fixed stars or our own sun' might be 'covered by the slags extruded during fusion', he adds that it is an ancient hypothesis: 'the ancients supposed, the sun would be veiled by increasing numbers of spots that would darken and eventually obscure it, something actually observed in our time, after the invention of the armed eye [telescope]': Leibniz, *Protogaea*, 5; fn: 5. Also see Oldroyd, *Thinking about the Earth*, 87.

> As in the beginning, before light had separated itself from darkness, fire seized everything, just so does one reckon that later, after the fire had been extinguished, everything was plunged into water. These things have been passed on through our sacred histories, which agree with the old stories of other peoples.[823]

Although Leibniz seems to tread the path most travelled when explaining earlier that it is possible for 'human knowledge to reach back' deep into history either via 'reasoning' and 'the tradition of scriptures', to the above citation he adds, 'But the inland vestiges of the sea offer the best support'. That is, for his ideas on the earth's history. 'For seashells have been transported onto the mountains', where amongst other marvels like amber and glossopetrae (sharks' teeth) dug up far from the sea, imprints of 'the coppery shapes of fish' are also found 'upon schistous stone'.[824] Although Leibniz attributes three different causes to the formation of solids, namely, fire, water ('purely to the movement and deposits of the waters'), and 'sometimes the combined action of heat and water', the third being the most problematic because 'where the causes vary, the verdict is ambiguous', his preferred explanatory device for fossil formation (indeed, all formation) is fire.[825]

In the eighteenth and nineteenth centuries, the 'two grand (and sometimes opposed) theories about the major agencies of geological change', as Oldroyd put it, would be water and fire.[826] Here, in the latter half of the seventeenth century, the fundamental difference between Steno and Leibniz, overlooked by scholars who dismiss Leibniz's *Protogaea* as relying too much on Steno's *Prodromus*, is the difference between water and fire. On the one hand, Steno, owing to his Stoic leanings and 'common physics', as previously discussed, argues that although the first cause of a solid's (a fossil's) formation is unknown because its metamorphosis is complete when the solid is found, nevertheless, it 'can be nothing else but a Porous surface of that Solid

823 Leibniz, *Protogaea*, 43, 45.
824 Leibniz, *Protogaea*, 15.
825 Leibniz, *Protogaea*, 41, 43.
826 Oldroyd, *Thinking about the Earth*, 86.

[in its particular place], and a subtile Fluid permeating those pores'.[827] For Steno, 'in the Creation' all things stemmed 'from the first Fluid', and all solids are born from fluids.[828] On the other, Leibniz claims that in the beginning was fire: 'heat and inner motion come from fire as from light, that is, from a very subtle and penetrating spirit … the motive cause which sacred history takes as the beginning of cosmogony'.[829]

In this conception, fluidity is an 'inner movement and a certain degree of heat', and solid matter has a 'twofold origin'.[830] First, solids 'cooled after being melted by fire'. Second, 'they hardened again after being dissolved by water'. The 'liquid material rushing over the earth's surface … deposited a huge quantity of matter in pulverized debris'. This debris 'formed different kinds of earth, and another part hardened to stone, with various layers superimposed'.[831] However, water in his world-making aside for the moment, Leibniz prefers to think of solids baking to hardness like bricks, perhaps because fire is easier to link to the furnace and art: just as 'bricks are formed out of clay in the ovens through human art', so nature makes alabaster, schist and so on.[832] Further, the metallic, sometimes 'coppery', parts of fossils are smelted in their moulds – I shall return to this in the subsequent section. Similarly to Hooke, Leibniz argues that 'Earthquakes also may clearly indicate that there are tunnels of fire, and huge volcanoes reveal fire dungeons extending far and wide'.[833] Finally, although Leibniz praises Burnet's construction of 'mountains and valleys out of collapses', and notes that 'Steno had already thought this way before about collapses and sediments, after visiting a considerable part of Europe and noting the vestiges of broken domes in various places', he

[827] Steno, *Prodromus*, 26, 32.
[828] Steno, *Prodromus*, 38.
[829] Leibniz, *Protogaea,* 5.
[830] Leibniz, *Protogaea,* 11. See also Hooke, *Micrographia*, 12: 'First, what is the *cause* of *fluidness*; And this, *I conceive*, to be nothing else but a certain *pulse* or *shake* of *heat*'.
[831] Leibniz, *Protogaea,* 11.
[832] Leibniz, *Protogaea,* 5, 49. According to Wilson, *The Invisible World*, 88, Leibniz 'tried persistently for years to obtain a copy [of Hooke's *Micrographia]*, receiving one finally in 1678'; however, Leibniz never cites Hooke in the *Protogaea*. That Leibniz did read the *Micrographia* may account for why his writing on heat bears a striking similarity to Hooke's in *Micrographia*, Observ. VI. *Of Small Glass Canes.*
[833] Leibniz, *Protogaea,* 49.

neither shares Burnet's dejection over living on ruins nor Steno's ideas on how Noah's flood changed the earth's face. Rather, Leibniz believes that the so-called ruin is ordered, and 'going further, I argue that the vaults were formed through *fusion*, while the seas were formed when salts reabsorbed watery vapors through deliquescence'.[834] In responding to these metaphysical distinctions between himself and Steno, Leibniz nevertheless presents water, in its guise in the *Prodromus*, as well as 'some petrifying spirit', as a feasible contender for the formation of a fossil – though he finds 'it harder to understand':

> If, however, someone does not want to accept that nature burns rocks, and prefers to think that the mud enveloping the fish turned to stone, either through time alone and according to the nature of the material, or through some petrifying spirit, or through another cause, and if one wants to assume that the metallic mineral was driven into the molds of the fishes, either in the beginning when the mass was raw and soft, or also later as a penetrating vapor, then I do not oppose it, though I find it harder to understand.[835]

By consistently anchoring these natural changes to local places and events both valuable and meaningful to the House of Brunswick, Leibniz employs art as nature and nature as history. For example, he reminds his readers of a 'recent' earthquake, which in '1691 reached from Italy to our borders, though it did not cross the West River'.[836] Firming the relation between earthquakes and fire, he references Agricola, the authoritative voice on mining and metallurgy, who 'says that there is much to indicate that this region [Hildesheim] once burned'. Leibniz adds that Agricola was also 'right that pumice stones come from places that have burnt, and it is well known that they are found not only in Sicily and Campania, but also in Germany'.[837] In Leibniz's scheme, the Harz Mountains, the 'highest region of lower Germany,

[834] Leibniz, *Protogaea,* 19. Italics added. Burnet, *The Sacred Theory of the Earth,* 74–75.
[835] Leibniz, *Protogaea,* 51, 53.
[836] Leibniz, *Protogaea,* 49.
[837] Leibniz, *Protogaea,* 51. Leibniz is referring to Agricola's descriptive, historical, and medicinal entry on pumice, in Agricola, *De natura fossilium (Textbook of minerology)*, location 2342 of 6835: '*Pumex* (pumice) is found in localities that have been on fire at some time or are burning now.'

one that is rich in metals', can be used to as a metonymy for 'other regions'. Although it appears similar at first glance to Steno's attempt, where Tuscany represents the earth, it is different from it in an important way: Leibniz prefers induction to modelling: if 'everyone contributes curiosity locally, it will be easier to recognise universal origins'. Although he adds that if a plurality of examples is not achievable, then his idea can serve as a model.[838] Namely, local parts can, collectively and on a global scale, represent and approximate the whole, and therefore 'universal origins'. The accumulation of various types of historical evidence, empirical and textual, allows Leibniz to conjecture that it is also not 'unreasonable to suppose that particular fires, unrecorded in our histories, occurred after the Great Flood, when combustible material was more abundantly spread across the earth [than now]'.[839] The idea that combustible material was more plentiful in the past seems to be a commonplace established by multiple comparative analyses between past and present descriptions of volcanoes, and was proposed by Hooke in his first *Discourse* lecture; he further added that perhaps untapped wells of 'fuels' remain, and that nature can probably make new ones should the need arise.[840] Thus, according to Leibniz, one should not

> wonder that heat turns earths to stone, that it melts metals into mineral masses, that it sublimes matter into fashioned bodies or deposits it as crystals when the heat of a solution is reduced. For most believe that there is fire contained in this globe, whose crust we have hardly explored.[841]

Further adding to artisanal metaphors popularised by Paracelsus and his

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[838] Leibniz, *Protogaea,* 3.

[839] Leibniz, *Protogaea,* 49, 51.

[840] Hooke, *Discourse,* 325–326. For instance, Athanasius Kircher, *the* authority on volcanoes, includes a historical account of Etna, given by one 'Mr. *Sandys*', in Athanasius Kircher, *The Vulcano's or, Burning and Fire-vomiting Mountains Famous in the World* (London: Printed by J. Darby, for John Allen …, 1669), 41, 42, in which account is described the loss of Etna's fuel and therefore fire-belching force by comparing present day Etna to Etna past: '*it raged so furiously, that Africa was there-of an astonish'd Witness*. This was about the Year of the World 3900. not long before Christ … But these great Eruptions of Fire, are not now so ordinary as they have been formerly; The matter which gave Fewel to it, being wasted by continual Burnings'. (Note: *Vulcano's* is a quarto collection of English'd extracts from Kircher's *Mundus Subterraneous* [1665]; the translator might be 'Benjamin Billingsly' – but this is purely conjectural on my part.)

[841] Leibniz, *Protogaea,* 49.

followers, such as the implicit blacksmith one in the beginning of this section, Leibniz borrows again from the alchemists by referring to 'volcanoes as furnaces and mountains as alembics'. Paracelsus also argued that practical knowledge trumps theoretical, and that there is no point to theory without application; and Leibniz explains that in this way, with furnaces and alembics, nature 'accomplished in her mighty works what we play at with our little examples', for in the earth, a thing like a fossil may take centuries to cool.[842] In contrast, the human lifespan lacks the earth's luxury of time, and production in laboratories and workshops is on a human-sized scale. Despite these restrictions, and in contrast to Paracelsus who pontificated that art perfects nature, Leibniz needs to show that art and nature are the same.[843]

> For nature is nothing other than a great art. And the entire class of artificial things is not always distinct from natural productions; for it is all the same whether some Vulcanius Daedalus discovers a thing in his furnace, or whether a stone-cutter brings it to light from the bowels of the earth.[844]

By 'Vulcanius Daedalus', Leibniz means someone adept in both the alchemical (Vulcan) and mechanistic (Daedalus) arts. I have traced this term back to Bacon, for whom experiential knowledge, 'whether they be experiments appertaining to Vulcanus or Daedalus, furnace or engine, or any other kind' is superior to knowledge acquired by taking texts on authority. Moreover, a cross-fertilisation of Vulcan and Daedalus gives 'a true and real illumination concerning causes and axioms', which is the bedrock of Bacon's idea that the furnace and the mine together are necessary for natural

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[842] Leibniz, *Protogaea,* 31, 33. According to Paracelsus, in 'The Physicians's Remedies', 99, 'only a great artist is able to discover them [natural remedies], not one who is versed only in books, but only one who has acquired his ability and skill through the experience of his hands …': Paracelsus, and Norbert Guterman (trans), in Jolande Jacobi (ed), *Paracelsus: Selected Writings* (London: Routledge and Kegan Paul, 1951), 158–160.

[843] The most succinct and potent expression of this idea in Paracelsus is as follows: 'The generation of all natural things is twofold: Naturall, and without Art; and Artificiall, viz. by Alchymie': Paracelsus, *Of the Nature of Things, Book I,* in Paracelsus, and J F (trans), *A New Light of Alchymie: Taken out of the fountaine of Nature, and Manuall Experience …* (London: Printed by Richard Cotes …, 1650), 1.

[844] Leibniz, *Protogaea,* 27.

philosophy (Chapter 2).[845] However, Leibniz's claim is that 'it', meaning nature and art, 'is all the same', and to support this, Leibniz needs to show with practical, human-sized examples, how 'the scattered vestiges of old things, of plants, animals, and artifacts wrapped in a new coat of stone' acquired their new coats.[846] In the process of showing, he can try to transform his readers' visuality from perceiving 'products of the imagination, not the eyes' to carefully observing that fossils are the remnants of once-living things, fragments of history captured and displaced spatially and temporally; then he can argue that the earth has, since Creation, 'experienced smaller fires, earthquakes, isolated floods, and deposits from floodwaters, which often occupied and changed large areas';[847] and thus present nature as history, 'our written history' replaying 'nature's grace'.

### 9.2 'IMPRINTED'

Leibniz assigns significance to perfect imprints of fish on stone, and shells dug up far away from the sea, specifically because of these unexpected and thus striking juxtapositions, which he argues should not be glossed with a 'games of nature' explanation. When discussing Hooke, Steno and Ray, we saw that the idea of fossils as the remains of once living beings is an ancient one; indeed, Woodward, listing the opposing opinions on what fossils are in his *Natural History*, remarks that 'It is indeed a *Question* of great *Antiquity*' how and why marine fossils 'were hurryed out of the *Ocean*, the Place of their *native Abode*, to *dry Land*, and even to *Countries* very *remote* from any *Seas*'.[848] Thus, he calls the *lusus naturae* explanation the 'new Expedient':

> And 'twas this last *Effort* that brought forth the *Opinion*, that these *Bodies* are not what they seem to be: that they are *no Shells*, but meer *Sportings* … They [the learned] imagined that this *shotrned* the *Difficulty*, because it

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[845] Bacon, *Advancement of Learning*, 64-65, 72-73. For the analogical use of alembics in this context, see Glacken, *Traces on the Rhodian Shore*, 413-414. For a broader summary, both practical and figurative, see Abraham, *A Dictionary of Alchemy*, 5-6.
[846] Leibniz, *Protogaea,* 3.
[847] Leibniz, *Protogaea,* 13, 75, 13.
[848] Woodward, *An Essay towards a Natural History of the Earth*, 37.

> spared them the Trouble of accounting for their [fossils'] *Conveyance* from *Sea*, which was what had so severely exercised all the former.[849]

Yet, Woodward, defending the belief that marine fossils are the '*Remains* of the *General Deluge*', claims that 'in reality, this [games of nature explanation] only *heighten'd* and *enhanced*' the problem of dislocation 'and render'd it still more *intricate*'.[850] Roger Ariew has shown, with examples from Avicenna and Albertus Magnus, that the organic origins opinion was also the 'standard scholastic doctrine', and that Aristotelians were concerned with explaining away not discrepancies of place but how petrified animals or plants 'left their form but not their matter or could have transferred their form from one matter to another'.[851] To this ancient idea, Leibniz adds another: when describing how the earth was first forged in fire, he claims, along with Descartes, that the earth was once a star, like one of the 'fixed stars or our own sun', which was 'covered by the slags extruded during fusion' that hardened when the earth was quenched. But, just as is the case with fossils, the idea is not a seventeenth-century one according to Leibniz:

> the ancients supposed, the sun would be veiled by increasing numbers of spots that would darken and eventually obscure it, something actually observed in our time, after the invention of the armed eye [telescope].[852]

The proposition that the earth is a sun, and that the sun's spots are slag, is another example of the inversion of values – which we have examined throughout with examples from Gilbert, Kepler, Hooke and others – from the complex, rare and divine to the simple, mundane and earthly. I suggest that without this change, without launching the earthly into the realm of the divine like Kepler, and without dragging the divine back down to earth like Ray and other physico-theologians, a historical investigation of nature would have

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[849] Woodward, *An Essay towards a Natural History of the Earth*, 40–41.
[850] Woodward, *An Essay towards a Natural History of the Earth*, 39–41.
[851] Ariew, 'Leibniz and the Petrifying Virtue of the Place', 36, 35–36. 'It seems wonderful to everyone that sometimes stones are found that have figures of animals inside and outside … and Avicenna says that the cause of this is that animals, just as they are, are sometimes changed into stones, and especially salty stones': Albertus Magnus, and D Wyckoff (trans), *Book of minerals* (Oxford: Clarendon Press, 1967), 52.
[852] Leibniz, *Protogaea*, 5; Descartes, *Principles of Philosophy*, IV.2–3.

been hardly possible, for divinity is associated with stasis not change. According to Ariew, the cost of Kircher and Becher's views, of their cutting ancient and mediaeval ontological ties between things that once lived and fossils in their natural philosophy, was a rejection of 'any historical account for the genesis of fossils'.[853] We have seen how Plot and Lister, with their treatment of fossils as nature's games, applied these new and ahistorical ways to know nature. In contrast, Leibniz in a sense completes the inversion of values by coupling two ancient ideas tied to the earth and art, fish fossils and the forge, which are supported by the radically instrument-mediated vision of the seventeenth century.

Optical instruments, as Leibniz implies in the *Protogaea*, allow for different practical and theoretical knowledge-making practices. Taking a moment to rant about a lack of interest in microscopy, as a sort of transition to the topic of fossils, Leibniz reveals his own instrumental empiricism: 'I also wish that the microscope, with which the Delft philosopher Leeuwenhoek has shown so much wisdom and care, were used for this investigation'. Namely, for looking past sensible qualities – which Leibniz argues are often the effects of underlying mixed causes – in this case to distinguish between the insensible parts of an object created from a combination of fire and water.[854] Wilson, possibly borrowing a detail from one of Hooke's observations on colour in the *Micrographia*, explains it thus: 'just as a mixture of blue and yellow powder produces the new appearance of green', so, as further put by her, Leibniz argues that 'qualities emerge as the result of confused perception of underlying [microscopic] texture'.[855] This is also why it is easy for nature to deceive, and why artisanal knowledge, or knowledge of nature's art on a human-sized scale, can help decompose mixed appearances.

As noted by both Rossi and Ariew, in Leibniz's metaphysics, even chaos is

[853] Ariew, 'Leibniz and the Petrifying Virtue of the Place', 37.
[854] Leibniz, *Protogaea*, 43. For radical instrumental empiricism, see Gal and Chen-Morris, *Baroque Science*.
[855] Wilson, *The Invisible World*, 59. For Hooke's microscopical observations of blue and yellow yielding green, see Hooke, *Micrographia*, 58, 69 It should also be noted that, according to Wilson, Leibniz argued that seeing the microstructure of particles that cause green nevertheless fails to solve the problem of how green is seen: Wilson, *The Invisible World*, 246.

ordered: disorder is only apparent, often the result of wrong perspective, or a faulty perception that a quality arose from a single cause instead of mixed ones.[856] From this one can infer that to Leibniz's mind, fossils are only perceived as signs of disorder, causing unnecessary anxiety about the earth's changing superficies, when observed from the wrong perspective. As Rossi stressed, the *Protogaea* begins (more or less) with the claim that God is not unreasonable and makes nothing without order (in a word, providence, which you will recall attracted Leibniz's editor Scheidt to the work).[857] In the *Theodicy*, making an implicit reference to the telescope as an instrument that dispels false perceptions, Leibniz mentions that there 'was a time when the planets were held to be wandering stars; now their motion is found to be regular'.[858]

Back on the other end of optical instruments, for what Leibniz perceives as a deplorable lack of interest in Leeuwenhoek's microscopy, he adds,

> I am often upset by the idleness of humans, *who do not bother to open their eyes* and take possession of an already completed science. For if we were that clever, he [Leeuwenhoek] would already have many imitators.[859]

As mentioned, Leibniz associates 'idleness' with the imagination, which is a preconditioned and thus passive *looking* versus actively *seeing* a fish fossil for what it really is: 'the remains of the fish'. Leibniz attempts to separate "seeing" a fossil from imagining it, which can be thought of as seeing historically instead of poetically (Chapter Eight) – the former being Bacon's way. Indeed, in a 1706 piece on plants and fish contained in stone, Leibniz states that calling these stones nature's games is 'a purely poetic idea'.[860] In this way, he turns the

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[856] Rossi, *The Dark Abyss of Time*, 52–55; Ariew, 'Leibniz and the Petrifying Virtue of the Place', 52–53.

[857] Rossi, *The Dark Abyss of Time*, 54: 'Deus incondita non molitur'; Leibniz, *Protogaea*, 3.

[858] Gottfried Wilhelm Leibniz, and C Gerhardt (ed), *Philosophische Schriften*, Volume 6 (Berlin, Germany: Weidmannsche Buchhandlung, 1890), 263, cited in Ariew, 'Leibniz and the Petrifying Virtue of Place', 52.

[859] Leibniz, *Protogaea*, 43. Italics added.

[860] Gottfried Wilhelm Leibniz, and Louis Dutens (ed), *Opera Omnia*, Vol. 2 (Geneva: Studio Ludovici Dutens, 1768 [1706]), 179: 'Plusieurs Auteurs ont appellé ces fortes de représentations de poissons, ou de plantes dans de pierres, *Jeux de la Nature*; mais c'est là une pure idée poëtique'. (Transcribed by me.) According to Dutens's footnote, the citation is from a piece extracted from the *History of the Paris Academy of Sciences* (1706).

tables on *lusus naturae* supporters, who, also recall, labelled Hooke's hermeneutical conclusions on fossils, earthquakes and volcanoes as stemming from 'Fictions and Romantick without any real Ground'.[861] But Burnet – of the sublime moment and ruined Earth – whom Leibniz both praises and criticises in equal measure, had yet another view of how to treat order and chaos, fact and fiction, in an authored Earth history. And the same procedures and new instruments pulling the heavens down to Earth and revealing the micro-world underpinned his historical imagination, too.

### 9.2.1 Actual Poetry

For Burnet, there is poetry, and then there is 'Philosophick Poetry'.[862] The former is the artificial kind penned by poets. The latter, remnants recorded by various cultures in various ways through the ages, which correspondingly describe major plot twists in the earth's past and future history – the intervals of great physical change between epochs (Figure 8).[863] Since, according to Burnet, philosophy is the study of 'Nature and Providence', it is a *philosophic* poetry because it captures God's hand in the earth's story.[864] 'And we must first consider how God hath ordered Nature, and then how the Oeconomy of the Intellectual World is adapted to it; for of these two parts consist the full System of Providence'.[865] Philosophic poetry can be excavated from texts with Burnet's approach to the study of history.

But Burnet is a historian, and takes care to warn why poets' verses should be treated with caution when read as potential history. While

> 'Tis true the Poets who were the most Ancient Writers amongst the Greeks … have deliver'd some things concerning the first ages of the World, that have a fair resemblance of Truth … yet, lest any thing fabulous should be

[861] Hooke, *Discourse, in Posthumous Works*, 407.
[862] Burnet, *Sacred Theory of the Earth*, Vol. 2, III.3.
[863] Burnet, *Sacred Theory of the Earth*, Vol. 2, III.3, 13; III.2, 6; Burnet, *Sacred Theory of the Earth*, Vol.1, II.3, 136; I.1, 3. For remnants, also see Levitin, *Ancient Wisdom in the Age of the New Science*, 186.
[864] Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated.
[865] Burnet, *Sacred Theory of the Earth*, Vol. 1, I.1, 3–4.

> mixt with them, as commonly there is, we will never depend wholly upon their credit.[866]

Poets 'are not to be trusted in all particulars' because they please the passions at the expense of historical authenticity: 'many times [they] exaggerate matters on purpose, that they may seem more strange, or more great, and by that means move and please us more'.[867] Nevertheless, the 'Ancients, especially the Poets in their description of the Golden Age' of the antediluvian earth 'exhibit to us an Order of things, and a Form of Life, very remote from any thing we see in our days'.[868] However, their descriptions must not be taken on authority unless first demonstrated 'by Natural Reason, or warranted by the Scripture'.[869] That said, Burnet admits that even the psalms are ambiguous: 'Poetical expressions, as the Psalms, seldom are so determinate and distinct, but that they may be interpreted more than one way'.[870] But if the psalms and descriptions from antiquity correspond, then both can be trusted as depictions of actual events. For example, referring to similar pieces that he believes describe the abyss of waters enclosed in the antediluvian earth, Burnet explains 'those expressions and passages that we have instanc'd in, are more fairly and aptly understood of the Ancient form of the Sea, or the Abysse, as it was enclos'd within the Earth, than of the present form of it in an open Chanel'.[871] Burnet's historiography is composed of an examination of evidence of congruity, of an order of things 'generally receiv'd', such as '*That the Torrid Zone was uninhabitable*', since 'not only the Poets, both Greek and Latin, but their Philosophers, Astronomers, Geographers, *had the same notions, and deliver'd the same doctrine*'.[872] Thus, having emphasised likeness and continuity in varying stories that he treats as different historiographical processes within his epochs, what Michel Foucault would a lot later call

866 Burnet, *Sacred Theory of the Earth*, Vol. 1, I.1, 3.
867 Burnet, *Sacred Theory of the Earth*, Vol. 1, II.6, 168.
868 Burnet, *Sacred Theory of the Earth*, Vol. 1, II.6, 168.
869 Burnet, *Sacred Theory of the Earth*, Vol. 1, I.1, 3.
870 Burnet, *Sacred Theory of the Earth*, Vol. 1, I.7, 59.
871 Burnet, *Sacred Theory of the Earth*, Vol. 1, I.7, 59.
872 Burnet, *Sacred Theory of the Earth*, Vol. 1, II.8, 183; II.7, 174. Italics added.

epistemes in his *Order of Things*, Burnet reimagines and rewrites new objective truths to explain away changes to the earth's superficies.[873]

### 9.2.2 Methodological 'Hinges'

Burnet's *Theory* is not 'sacred' because it takes the scriptures as the highest authority, but because it revolves around significant moments of earthly change caught and preserved in remains of 'Philosophick Poetry'.

> This Theory of the Earth may be call'd Sacred, because it is not the common Physiology of the Earth … but respects only the great Turns of Fate, and the Revolutions of our Natural World.[874]

These moments are 'truly the Hinges upon which the Providence of this Earth moves; or whereby it opens and shuts the several successive Scenes whereof it is made up'.[875] Thus they are the focal points of Burnet's historiography. From an epistemological perspective, they are 'the Seeds of great knowledge, or heads of Theories fixt on purpose to give us aim and direction how to pursue the rest that depend upon them'. From a historiographical perspective, 'these heads, you see, are of a mixt order, and we propose to our selves in this Work only such as belong to the Natural World' because, according to Burnet, Earth history has greater import than 'the Rise and Fall, and all the Revolutions, not of a Monarchy or an Empire, of the Grecian or Roman State' because it chronicles the life of 'an intire World'.[876] His motivation is 'to see those pieces of most ancient History, which have been chiefly preserv'd in Scripture, confirm'd a-new, and by another Light, that of Nature and Philosophy'; and to apply the same technique to congruous classical sources, resolving them 'into plain natural History'.[877]

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[873] Michel Foucault's epistemes are the yields of a similar intellectual intuition: that there is no change within epochs, only breakage between them: Michel Foucault, The Order of Things: An Archaeology of the Human Sciences (New York, USA: Vintage Press, 1994). But Burnet is better by far.

[874] Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated. Magruder (2009), 452.

[875] Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated.

[876] Burnet, *Sacred Theory of the Earth*, Vol. 1, I.1, 3–4.

[877] Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated; II.8, 182. Although Burnet uses the term 'natural History' here, recall that its meaning has changed.

For example, to lend empirical support to his claim that we live on ruins of the antediluvian earth, Burnet employs a trope invented by Galileo in the *Sidereus Nuncius* (1610), of the moon's *maculate* surface, which was a conceptual idiom by Burnet's time, used to great effect in various ways by his fellow Englishman and peer Hooke, and others (Chapter 6). Like them, Burnet compares the earth and the moon to craft an argument by analogy:

> And such a body as the Moon appears to us, when 'tis look'd upon with a good Glass, rude and ragged; as it is also represented in the modern Maps of the Moon; such a thing would the Earth appear if it was seen from the Moon.[878]

But remember that unlike Kepler, Wilkins and Hooke, Burnet's flight serves to solidify the conclusion that 'They are both [the earth and the moon] in my judgement the image or picture of a great Ruine, and have the true aspect of a World lying in its rubbish.'[879] When Burnet tells readers that the earth had a different form before the deluge, and that this is 'our first discovery at a distance', he is still observing telescopically, this time at the earth's past. When he then takes us on an imaginary journey as visitors from another planet who fly to Earth through the air, so that we can picture it as a physical body like the moon, and then magnify particulars that underscore its superficial imperfections, it becomes obvious, both from his choice of metaphor as well as his thought experiment, that new optical instruments like the telescope have transformed his historical imagination.

By applying some of the theories and practices of the new science to his exegeses, Burnet attempts to confirm that these big events of Earth history actually happened. While he is certainly a cautious and sceptical historian, Burnet reads tropes like Galileo's into both the scriptures and classical texts to discuss phaenomena observable in the present – like mountains, the fragments of a shattered superficies jutting out.[880] So for Burnet, figurative interpretations

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[878] Burnet, *Sacred Theory of the Earth*, Vol. 1, I.9, 74–75.
[879] Burnet, *Sacred Theory of the Earth*, Vol. 1, I.9, 75.
[880] For Burnet's caution and scepticism, see Levitin, *Ancient Wisdom is the Age of the New Science*, 185.

open the past to the novel scrutiny of the present.[881] Like an optical instrument, figurative interpretation allows seeing beyond surface appearances to the intended meaning. This is a prime example of the new science cutting and polishing historical thinking and experience, which thereby shapes Burnet's historiography.

### 9.2.3 The '*Plot or Mystery*'

Another outcome of the new science seeping into the historical imagination is the consideration of what constitutes history. Burnet's narratively aware investigative procedures underscore how the face of history changes as much as the face of the earth – different times represent history in different ways. His response to critics (we will meet one of them, Bernardino Ramazzini, in 9.3.1) is that radical empirics, with little talent for exercising the imagination, cannot discern philosophic poetry from artificial poetry, so they cannot order the confusion of history. That is, they fail to narratively structure the 'variety of Parts in a due Contexture,' meaning composition, 'with something of surprizing aptness in the harmony and correspondency of them'. Instead, 'this they call a Romance' – an idea with unobservable effects, and therefore 'without Truth in Reality'.[882]

Yet Burnet's method may seem prosaic, for it was a hermeneutic engaged in by many physico-theologians and natural philosophers in the seventeenth century.[883] And it, too, imposes constraints on what is knowable about Earth history. For Burnet, all other history is checked against not only his view of the current state of the earth but also his interpretation of congruous scriptural accounts. Moreover, all other history is of secondary importance to intervals of profound change – the deluge and the coming conflagration – moments where providence twists the plot so that the sins of Man and nature's changes correspond. But on top of these constraints sits Burnet's most

881 For Burnet and figurative interpretation, also see Rappaport, *When Geologists were Historians*, 140–141.

882 Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated; II.1, 121. Dyche, *A New General English Dictionary*, CON.

883 For example, Hooke, *Discourse of Earthquakes*, 404–407; Steno, *Prodromus*, 48, 107–109.

idiosyncratic claim that for something to be a theory like his own work, it also needs to be romantic:

> but such Romances must all Theories of Nature, and of Providence, be, and must have every part of that Character with advantage, if they be well represented. There is in them, as I may so say, a *Plot* or *Mystery* pursued through the whole Work.[884]

That is, Burnet argues that a theory like his has more truth if it has the narrative structure of 'a *Plot* or *Mystery*' – if it has elements of both history and philosophic poetry. These are not tensions between history, or actual events, and story, or fiction; Burnet's Earth history is authentic because of the quiddity of his poetry: his conception of poetry as an inherent part of the earth's plot. As such, according to Burnet's reformulation, both history and philosophic poetry are to be discovered; the latter is not to be created like artificial poems, romances and fictions.

> And when they are clearly discover'd, well digested, and well reason'd in every part, there is, methinks, more of beauty in such a Theory … And that solid truth that is at the bottom, gives a satisfaction to the Mind, that it can never have from any Fiction, how artificial soever it be.[885]

Burnet's approach feeds off an imagination expanded by the new worlds exposed by new instruments, which change his preconceptions on 'truth'. The novel idea that what should engage historiographers is, as put by Hayden White many years later, 'the extent to which the discourse of the historian and that of the imaginative writer overlap, resemble, or correspond with each other'.[886] These points of intersection, according to Burnet's reading and writing of history through seventeenth-century eyes, are actual history. Leibniz added Burnet's ideas on actual history to his own historian's toolkit in the *Protogaea*.

[884] Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated.
[885] Burnet, *Sacred Theory of the Earth*, Vol. 1, Preface, unpaginated.
[886] White, *Metahistory,* 121.

9.2.4 Leibniz feigning

Despite Leibniz's mistrust of the imagination, the *Protogaea*, with its conjectural historicities, which were scorned by his successor and editor Scheidt, is woven together with elements of Burnet's definition of poetry. Moreover, the new and instrumentalised practices of looking that Leibniz values in Leeuwenhoek's approach train the imagination, shaping and reshaping perceptions of petrified bodies. Yet for Leibniz, this reshaping by telescope, microscope and so on prevents deception because it allows the senses to penetrate beyond surface appearances or mixed qualities. And with the imagination in reins and the eye armed, Leibniz argues that in 'most cases, the kind of fish can be recognized at first glance … For the imitated [fossilised] fish perfectly resemble real fish, *right down to the finest details* of their fins and scales' whereas resemblances always lose this necessary information.[887]

To clarify, Leibniz provides a 'local example':

> the investigation of a remarkable work of nature that produces the coppery shapes of fish upon schistous stone … Often one sees in these stones, which some call ichthyomorphic, the shapes of fish whose contours have been traced precisely, as if an artisan had inserted carved metallic material into the black stone.[888]

Here, he first interweaves his blacksmith's 'cosmogony' of fire with his claims about art and fossils. In a mine in the Saxon town of Eisleben 'there occur … various layers of coppery schist', which 'consists of sheets' and is 'easy to split'. Leibniz owns 'a fragment of such a stone, each side of which is imprinted with the image of a different fish'[889] – a verso and recto pictorial history. Again, fossils are not products of nature's games, a fancy that Leibniz blames on 'the empty words of philosophers'. Instead,

> I have in my hands a barbel, a perch, a bleak, sculpted in stone. Not long ago an immense pike was dug out of a quarry, its body bent and its mouth

[887] Leibniz, *Protogaea,* 45.
[888] Leibniz, *Protogaea*, 43. Italics added.
[889] Leibniz, *Protogaea*, 43–45.

> open, as if it had been caught alive and turned to stone by the power of the Gorgon.[890]

Leibniz has in his hands *real* fish.

To translate his meaning into understanding in the minds of his readers, he constructs an image pieced together from visual and haptic observations supported by analogous artisanal practices and fragments of history. First, that the fish are real 'is supported by the fact that there are many fish enclosed in the same place, and that there are nothing but fish there'.[891] To account for how so many fish ended up buried together, Leibniz provides a historical argument: 'a more obvious and uniform cause' for why 'a great number of these [fish] images is seen in the same place' is that in the past 'an immense lake, together with its fish, was filled with earth' (possibly by an earthquake) that 'later hardened'. Further linking this feigned past event to present physical observations, Leibniz relies on the knowledge of miners, noting that there are 'still prominent lakes near Eisleben', where these fossilised fish can be found in only one 'layer', horizontal and 'enclosed on each side by walls of the hardest stone'; finally, he claims that only this layer with fish 'is especially suited to the fire, for no other copper ore obeys the smelter more easily'.[892] (Although the kiln imagery in Leibniz's description of this layer is obvious, he never explains why it is more 'suited to the fire' than other layers or veins.) Thus, as the earth-filled lake 'later hardened to stone it was imprinted with the remains of the fish … [and] after the remains of the animals were long gone, the spaces they left were filled with metallic matter'. As mentioned, his conception of artisanal practices as nature's art on a human scale allows Leibniz to argue by analogy that 'nature's great fire' can form schist and so on 'just as bricks are formed out of clay in the ovens'; and that this same 'force of heat' separates the copper from the mud, the molten metal then pouring into 'the cavities left behind by the fish' like a natural foundry.

For example, goldsmiths employ a similar method to nature's when

[890] Leibniz, *Protogaea*, 45.
[891] Leibniz, *Protogaea*, 53.
[892] Leibniz, *Protogaea*, 43–45. See also, Leibniz, *Opera Omnia*, Vol. 2, 176.

making metal animals from real ones: by covering 'a spider of some other animal with a suitable material' (like plaster), and 'leaving a small opening' through which to 'pour silver' after the plaster is baked 'to stone' and the ashy remains forced from the mould with mercury, when 'the shell is removed, they uncover a silver animal, with its entire complement of feet, hairs, and fibers, which are wonderfully imitated'. Similarly, in the Osterode and Eisleben mines, 'one recognizes immediately not only the fish, but also the kind of fish, its true size and the dimensions of its parts, its scales, and all the rest'.[893]

By describing in detail how artisanal techniques and nature's processes can produce similar objects, and by referring to these objects as nature's records, Leibniz invokes the first law of history, further guarding the eye, armed with new optical instruments, against the poeticism of the imagination and nature's deception; and hence, his historical work from fiction. Again, the artifice protects Leibniz from nature's deception as well as from poeticising. In this way, and by rejecting the 'new expedient' of nature's games as 'pure poetry', Leibniz supports ancient (and mediaeval) ideas on the earth and fossils with the new instruments and practices of the new science; in turn, he uses these mixed histories to support, and to quell anxieties about, his ontology of fossils.

### 9.3 'By Slices, as it were, through length of time'

> Even if we suppose that these lakes were under the earth before they were filled in, we would still have to recognize that the onetime surface of the earth had been entirely transformed and ultimately scraped away.[894]

Leibniz's feigning on the earth-filled lake of coppery fish fossils has two functions in his replacement of history with nature. Alone, it serves as a causal hence

[893] Leibniz, *Protogaea*, 49, 53. For the awful process of casting metal animals from real ones, and what can be learnt from this, see Pamela Smith's 'Learning Through Reconstruction', at Yale University Art Gallery's YouTube channel, which is part of her Making and Knowing Project (accessed 2018): https://www.youtube.com/watch?v=zlOyAdg1Td4. Also see the 'casting from life' presentation section from 'The History of Science: Snakes, Lizards, and Manuscripts' at Columbia University's YouTube (accessed 2018): https://www.youtube.com/watch?v=NhRXVKDlYjo.

[894] Leibniz, *Protogaea*, 55.

historical supposition on how fish fossils ended up in a mountain. As the foundations for a second conjecture, the buried lake becomes the first physical 'tier' of a two-tiered Earth: 'the earth has two tiers, so to speak: the one was formed while the fishes were in their lake; the second arose after an immense mass of soft material covered them and collected upon them'. This second tier is composed, in general, of 'several layers of splittable stone … covered with very hard rocks, then with clay, and finally with common black earth, which people cultivate today'.[895] Although Leibniz dismisses the idea (early on in the *Protogaea*) that 'human curiosity' is at a stage where it can 'describe the kinds of layers of earth that extend through the various territories', this impediment fails to prevent him from borrowing Steno's hypothesis on the earth's layers or strata, and historicising it: moving from the present, represented by the 'common black earth', to the past by digging through the layers of the second tier, because 'you can be sure how much change time has wrought by comparing the present face of things to what history describes'.[896] His approach, as Cohen and Wakefield have also noticed, 'transform[s] the different episodes represented in this spatial succession into a temporal and causal narrative'.[897] As mentioned, it is likely that Leibniz got this idea from Bernardino Ramazzini, whose *De fontium mutinensium* (1691) he cites: 'I observed … and saw for myself what that exceptionally learned physician in Modena, Bernardino Ramazzini, describes in a fine little work' on natural springs and wells in the Italian duchy of Modena.[898]

### 9.3.1: 'We Understand by History'

Ramazzini collaborated with Giovanni Battista Boccabadati, lecturer of hydraulics at Modena from 1684 to 1689, to work out why any well dug anywhere in the duchy 'to the depth of about 63 Foot', and the bottom pierced 'with a great Auger [giant corkscrew drill], which when it has been

[895] Leibniz, *Protogaea*, 55.
[896] Leibniz, *Protogaea*, 11, 121.
[897] Cohen and Wakefield (eds), *Protogaea*, xx–xxi.
[898] Leibniz, *Protogaea*, 125.

driven down 5 Foot deep' would cause the well to 'boil up' with water, 'casting up Sand, Pebbles, and many other things'.[899] Ramazzini enlisted the help of local well diggers, who first had to bore through layers of both man-made and natural strata before breaking into Modena's subterraneous water supply, descending into the depths of the wells to confirm their descriptions for himself ('I went down into the bottom of a *Well* in the beginning of *February*, holding a lighted Candle in my hand …'), and afterwards devised experiments with several pipes attached to a vessel of water, which represented the wells and 'a great Repository of Waters' respectively (Figure 10). [900] Yet Ramazzini's *De fontium* is less relevant to hydraulics than it is to Earth history.

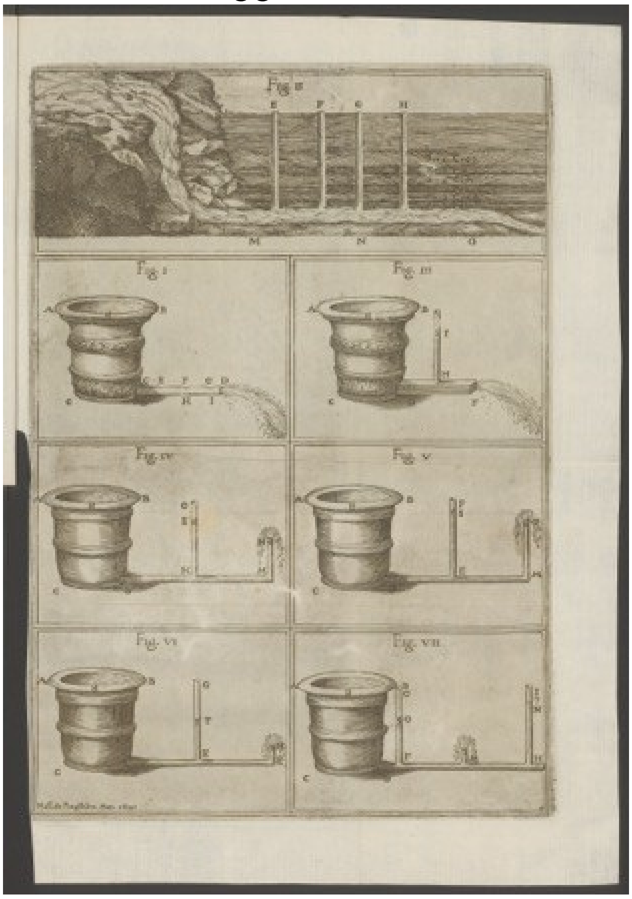

*Figure 10: Wells bored through Modena's strata into its water supply ('Fig. II'), and hydrostatic experiments below, in Ramazzini's* De fontium mutinensium *(1691). Credit: Zentrabibliothek Zürich, NG 420,4, Public Domain Mark.*

While working on *De fontium*, Ramazzini was compelled by a missive from Marcello Malpighi to include a history of the earth based on his studies of its interior structure, as an antithesis to the 'apriorism' of Burnet's *Sacred Theory of the Earth*.[901] Malpighi had spent decades transferring and translating

[899] Bernardino Ramazzini, and Robert St Clair (trans), De *fontium mutinensium admiranda scaturigine; tractatus physico-hydro-staticus* (Mutina, Italy, 1691), in Robert St Clair (ed), *The Abyssinian philosophy confuted …* (London, England, 1697, Early English Books Online Text Creation Partnership, http://name.umdl.umich.edu/A57681.0001.001, re-accessed 22/12/22), 4, 31, 60. (Henceforth: *De fontium*.) Note that although I use and cite the English'd *De fontium*, I cross-reference it with Bernardino Ramazzini, *De Fontium Mutinensium admiranda scaturigine tractatus physico-hydrostaticus* (Mutinae, Italy: typis Haeredum Suliani), at Zentralbibliothek Zürich, Shelf Mark NG 420,4, http://dx.doi.org/10.3931/e-rara-35346, re-accessed 22/12/22. Domenico Bertoloni Meli, *Thinking with Objects* (Baltimore, USA: John Hopkins University Press, 2009), 187.

[900] Ramazzini, *De fontium*, 11; Ramazzini's experiments start on page 31.

[901] Rappaport, *When Geologists were Historians*, 143.

the instrumental empiricism of Galileo from physics to other science, such as medicine. Francesco Luzzini argues that where field research such as Ramazzini's (and a little later, Antonio Vallisneri's) was concerned, this proved doubly difficult, for it required taking techniques more at home in laboratories and workshops down into mines and wells, where they intersected with artisanal knowledge.[902] Although Ramazzini criticised Burnet's *Theory* in Chapter 4 of *De fontium*, he rarely limited himself to hydraulics in other chapters, instead taking care to chronicle a history of Modena's subterraneous regions throughout his work on wells. According to Domenico Bertoloni Meli, Ramazzini's work on 'the science of waters' was excluded from reprints whereas his work, or parts thereof, on the local history of Modena's subterraneous strata and the earth in general were reprinted as well as translated into English.[903] Thus, these later reprints testify to *De fontium's* historical merit. Moreover, Ramazzini's actual motivation for risking a fall into 'Hell', with well-diggers as his Virgil, was historical.[904] For him, wells and mines were not only marvels of art but also tools for studying earth's past, enabling the empirical narration of Modena's history by excavating it from Earth's entrails. The changing epistemic status of wells with respect to their content of raw historical knowledge had historiographical ramifications. Wells and mines became the sites of an imaginative turn, instigating a historiographical watershed.

In the preface to *De fontium*, Ramazzini grieves over the earth's unknowability. Unlike cadavers that lie open before the anatomist, the earth's body remains closed: we 'know the Body of the Earth superficially' – the equivalent of knowing the human body by its skin. He laments that we can *never* know the earth so intimately: 'we can observe nothing but its outward side, and therefore we are ignorant of the more beautiful things that are hid … for there is *no way* by which they may be known', these deeper cavities that

902 Francesco Luzzini, *Theory, practice, and nature in-between: Antonio Vallisneri's Primi Itineris Specimen* (Berlin, Germany: Max Planck Institute for the History of Science, 2018), 17–18.
903 Bertoloni Meli, *Thinking with Objects*, 189.
904 Ramazzini, *De fontium*, 12.

'Humane Industry cannot Reach'.[905] Although this may sound as if Ramazzini is parroting traditional Aristotelian ideas about the earth, his careful curbing of empirical knowledge is taken not from Aristotle but from Agricola:

> For although the Miners have gone down into the Bowels of the Earth many Fathoms, yet they have never gone much deeper than half a Mile, which by *Agricola* is said to be the greatest Depth of the Mines. But what is that to the Depth of the Earth, whose Seme. Diameter is said to be 3600 Mile.[906]

Ramazzini believes that Agricola is a better expert on empirical research, and therefore also an expert on its limits. Perhaps also because Aristotle's account of the formal causes for various objects dug up, including 'the kinds of stones that cannot be melted … and ruddle, and sulphur,' was vague, Ramazzini prefers the empirical observations and measurements delivered by Agricola's *De re metallica*, with its alloy of alchemical and metallurgical knowledge.[907] That we can go no deeper than 'half a Mile' is a disturbing fact for Ramazzini, and stems from his opinion on how knowledge is obtained: either by the confirmation of observations and 'many thousands of Experiments,' or by cross-referencing several authorities, ancient and modern, on a specific subject – a process he refers to as 'by strong Reasons and Authorities' when describing Giovanni Battista Aleotti's efforts to correct the description of a river's path.[908] Ramazzini's pessimism over the earth's unknowability is the price he pays for epistemic certitude. That is, he enforces these methodological constraints to guard his philosophical 'conjectures' from speculation, from the invention of *imaginary* rivers, and applies the same strict practices to his historiography in a similar effort to protect history from 'feigning'.[909] In

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905 Ramazzini, *De fontium*, unpaginated, 116.

906 Ramazzini, *De fontium*, unpaginated.

907 Aristotle, *Meteorologica*, 3.6, 378$^{a}$; Rampling, 'Theory choice in medieval alchemy', 9; Norris, 'The mineral exhalation theory of metallogenesis in pre-modern mineral science'. Georgius Agricola, Herbert Clark Hoover and Lou Henry Hoover (trans and eds), De re metallica (New York, USA: Dover, 1950 [1556]), xxviii–xxix, 248. With respect to *De re metallica*, one should note well not to trust the translators of this edition who are blatantly biased. The page numbers that I provide in this reference are an example of where the primary source material contradicts the translators' lies about Agricola's thoughts on alchemy and alchemists.

908 Ramazzini, *De fontium*, 3, 110.

909 Ramazzini, *De fontium*, 57–61.

Ramazzini's opinion, historians cannot allow themselves any more leeway than philosophers: history should accurately portray the past, and therefore the present. This precept harks back to Cicero's *De Oratore*: because 'history is the teacher of life,' everyone knows 'that the first law of history is to dare to say nothing false, and again to omit nothing which is true'.[910] In other words, historians cannot afford to be poets, and idea, as we have seen, from Aristotle's *Poetics*. Yet there are 'Apertures, as Nature has made of her own accord, or by Mines and Wells'. Ramazzini uses wells, apertures of art, to turn himself into an 'Eye-witness' of history. Listing objects he has seen 'in the greatest Depths of these Wells', such as 'great Bones, Coals, Flints, and pieces of Iron' as well as shells and trees, he remarks, 'These are the things which belong to the History of the *Wells of Modena*'.[911]

Similarly to Dugdale digging around in the drained fens of the Great Level, Ramazzini observes several species of subterraneous trees, also not 'cut by Men's Hands', and dares to speculate that 'these Woods were only the Habitations of wild Beasts in former times' and to state ''tis manifest Proof that this Ground was once expos'd to the Air'.[912] Echoing him, Leibniz claims that the 'Reed roots, rotten trunks, twigs and stems, tree leaves, and the shells scattered among them declare that this *vallus* [a layer of 'a kind of soil' encountered about 50 feet down] was once exposed'. Further, upon noting that a stratum of clay is sometimes 'full of Cockle-shells' and that 'the last Plain, in which the Auger is fix'd' into the well is 'soft, and sandy, and mixt with much Gravel, and sometimes full of Sea-Products', Ramazzini proposes – like Dugdale, Hooke, Steno and Leibniz – that the sea and land have swapped places: 'in the first beginning of the World, all this Plain … was once a Sea, and a part of the *Adriatick*'.[913] But on account of sediments washing down from the Alps and Apennines, 'this Ground did grow up by degrees, and by many Lays or Beds, to the height we do now see'. Finally, like them, Ramazzini

[910] Cicero, *De Oratore*, 2.9.36, 2.15.62. Also see A J Woodman, *Rhetoric in classical historiography: Four studies* (London, England: Areopagitica Press, 1988), 81.
[911] Ramazzini, De *fontium*, 4. Bertoloni Meli, *Thinking with Objects,* 187.
[912] Ramazzini, *De fontium*, 14, 27, 28.
[913] Ramazzini, *De fontium,* 26, 27, 85, 104–105.

supports his claims with the authority of history as well as first-hand observations, citing, for example, Aristotle's description of the Nile delta (discussed in Chapter 5 with Hooke and in Chapter 8 with Dugdale).[914]

Indeed, Ramazzini's conclusion is Hooke's: recall that Hooke attributes nature's stasis to art, arguing via Aristotle that dry land swaps places with the sea over long periods of time – periods long 'in comparison of our short [human] Life', which is too brief to sense such gradual changes. Thus, nature's changes are stopped by art, and 'the memory of [these changes] is lost'.[915] Leibniz, too, observes that the 'face of the globe has been transformed by so many people that I believe humans owe a great deal part of the land they inhabit to themselves'. The more we advance art, the more we control nature, because we can imitate it on a smaller scale: 'These days art has advanced so far that, in some places, you see land lower than the sea, meadows below a river, and water that seems suspended in air, restrained from overflowing by a very long dam'. Likewise, Ramazzini concludes that without constant human intervention, nature destroys objects of art: for example, this is 'the common Fate of Cities that are plac'd in the Plains, that after many Ages they are almost half buried' or are 'carried by the force of Rivers into the Sea'. Borrowing a common metaphor for these effects, Ramazzini explains that they are 'Injuries of Time: a sure Proof, that there is nothing constant and firm in this world'.[916]

> But because (to use *Aristotile's* words) the things are done in great length of time in respect of our Life, they are hid from us, and the ruine of all Nations does happen before the change of these things, is told from the beginning to the end.[917]

Humans cannot bear testimony to these changes just as they cannot know the earth inside out: 'yet the thing it self speaks that they have truly happened, and will still follow'.[918] In this respect there are two flows of time

914 Ramazzini, *De fontium*, 105–106
915 Hooke, *Discourse of Earthquakes*, 324.
916 Ramazzini, *De fontium*, 152–153
917 Ramazzini, *De fontium*, 152–153
918 Ramazzini, *De fontium*, 152

constantly interrupting each other: human time, in which nature appears static, and nature's time, in which all things are in flux. It is a realisation reminiscent of a meditation on time in Augustine's *Confessions* (that Leibniz read carefully). Struggling to grasp the slippery notion of what time is (for example, 'If nobody asks me I know: but if I were desirous to explain it to one that should ask me, plainly I know not'[919]), Augustine argues that "time" preceded Man as one of God's creations, but that there is also "time" as perceived and measured by the human mind – that is, a human *experience* of time. So, although Augustine feels estranged from time as an abstract creation, contemplating his experiences of it leads him to conclude that 'time is nothing else but a stretching out in length, but of what, I know not', and that it is measured in the mind. Since the present 'extends both ways', the mind either expects, experiences the present, or remembers.[920] Similarly, Ramazzini feels estranged from the 'great length' of nature's time, which precedes man, and finds solace not in contemplation but in the exposed strata of the wells, which slice time like Augustine's categories of past, present, future, and allow him to form a relation between nature's time and 'our Life'. He perceives an order in the layers, a natural succession, which shows him that order will proceed because it has preceded, allowing him to enforce an epic narrative structure on nature's history:

> Yet this growing up of the Ground, which is observ'd by the great Depth of these Wells … was but slowly made, and by Slices, as it were, through length of time, as the several Lays of Earth do witness, which are observed in all Wells constantly in an equal Order and Distances when they are digged; so that this growing up of the Ground so well distinguish'd, and so remarkable in the digging of all Wells, ought to be thought rather the Product of so many Ages[.][921]

The way to notice that natural changes have occurred in an orderly manner,

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919 Augustine and William Watts (trans and ed), *Confessions,* Vol. 2 (London: William Heinemann, 1912), 239.
920 Augustine, *Confessions*, Vol.2, 263, 289.
921 Ramazzini, *De fontium*, 116; see also Rappaport, *When Geologists were Historians*, 146. Italics added.

then, is to dig perpendicularly below surface appearances, so as not to skew the strata and their 'equal Order'. Recall that the importance of fossils (and indeed extinction) for Hooke has less to do with fossils themselves than with what they, as traces, imply about the earth's history as a physical body – its changes through time. For Hooke, fossils, these "static" stones, are paradoxically a synecdoche of nature's dynamics, and because of this, they allow him to argue that order is not destroyed but created by nature's motions. It is this use of space as time, of giving time physical dimensions that can be handled and studied, which so excites Leibniz, who concludes the *Protogaea* with fossils and layers 'in place of history'.

### 9.3.2 'LAYERS'

'Because of a striking wonder of *all-changing nature*,' Leibniz explains, 'one discerns under Modena, present seat of the princes of Este, a vast lake hidden in the earth, covered by a city and a field as if by a vault'.[922] Indeed, that the eighteenth-century encyclopaedist Ephraïm Chambers mentions Modena when summarising descriptions and techniques of well-sinking in his *Cyclopaedia* (several editions) testifies to its lasting renown in this respect: 'Cassini observes, that in many places of Modena, and Bologna, they make themselves *wells* by the same artifice' as described by 'Mr. Blondel' when informing 'the royal academy of sciences of a device they use in the lower Austria'.[923] Leibniz conveniently links Modena to the *Protogaea* because the House of Este's territories (he mentions the 'domain of Este') were 'once possessed by ancestors [the House of Welf] of the most serene duke of Brunswick'. However, that 'under Modena … a vast lake [is] hidden in the earth, covered by [the] city and field as if by a vault', so that 'wherever one proposes to sink a well … one has a living, springing, continual and, in a word, ready-made stream', reveals its real usefulness to him: as a place where he

922 Leibniz, *Protogaea*, 123. Italics added.

923 Ephraïm Chambers, *Cyclopaedia … Fifth Edition,* Vol. 2 (London: Printed for W Innys, A Ward, et al., 1743), WEL–WER. Google books. Re-accessed 24/12/22.

might show his readers how nature stands 'in place of history'.[924] For him, it is important that the cause of the 'lake' under Modena is *nature's* changes. If Leibniz is to replace history with nature – he wrote to Thomas Burnet of Kemnay (or Kemney)[925] that the former was still in need of a 'science of proof' for the verification of its facts – then he needs to show his readers not only that the two are interchangeable but that studying strata and fossils provides more trustworthy construction of the earth's history as well as corroboration of historical texts.[926] To support his claims on the earth's second tier of which Modena forms the most superficial part (the first tier being the buried lake bottom), and to avoid nature's deception, Leibniz turns to art again: sites where wells are sunk become archaeological digs, and the detritus of natural and man-made strata bored out of each is a sort of earth core sample of a past brought to light. Although his description of Modena's strata coheres with Ramazzini's in number, for both describe eight layers (see 'Fig. II' in Figure 10), Leibniz's use of it differs in important ways.

The historical theme explored in Ramazzini's work is, in his own words, limited to the local '*Wells of Modena'* – his subject matter. In contrast, Leibniz has loftier aims, as well as a historic dukedom to preface, of which Modena's wells are but a part. At the same time, attempting to realise (as much as he is able) his inductive idea, explained earlier, that contributing 'curiosity locally' all over the earth would make it 'easier to recognise universal origins', Leibniz compares the physical 'layers' in Modena's wells with 'analogous ruins of earths' in 'Este in Lombardy' and elsewhere, ending the *Protogaea* in a well in Amsterdam. Hence, his historical experience differs from Ramazzini's, and as put by Cohen and Wakefield, 'reflects the tension between the criticism of local "documents" (fossils, curiosities) and the systematic attempt to construct

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924 Leibniz, *Protogaea*, 121, 125. Italics added.

925 Not to be confused with Thomas Burnet of the *Sacred Theory*.

926 Gottfried Wilhelm Leibniz, and C I Gerhardt (ed), *Die philosophischen Schriften von Gottfried Wilhelm Leibniz*, Volume 3 (Berlin, Germany: Weidmannsche Buchhandlung, 1887), 193–194: 'Mais la Philosophie pratique est fondée sur la véritable Topique ou Dialectique, c'est a dire, sur l'art d'estimer les degres des probations … et peuvent servir de commencement pour former la science des preuves, propre a verifier les faits historiques …' (Transcribed by me.) See also Rappaport, *When Geologists Were Historians*, 69–70.

a global narrative'.[927] Leibniz attempts to ease the tension by applying the new investigative procedures of the new science to history as well as historical methods to nature.

Although Leibniz and Ramazzini both perceive an order in the strata, it is a different kind of order, and so Ramazzini's lamentations are not sung by Leibniz, who worries neither that we cannot be anatomists of the earth nor that we never will be; indeed, Leibniz is optimistic about human knowledge and its trajectory, and this allows him to trust in art as a means to true knowledge of nature – such as when he conjectures that metallic fish fossils are made the same way as the silver spiders of goldsmiths. By practicing nature's art on a human scale, one also imitates, as put by Glacken, 'on a small scale the acts of God in the universe'.[928] I suggest that Leibniz's optimism is an outcome of seventeenth-century instrument-mediated observation, imagination, and representation, which lengthened the human life span by allowing us to peer deeply into all things – including the earth's past.[929] In Leibniz's words,

> Through the grace of God we now possess excellent instruments for examining the secrets of nature, and in these enquiries we can achieve more in a single year than our ancestors achieved in ten or a hundred years.[930]

As explained in the previous section, Leibniz argues that optical instruments reveal the actual causes of things behind conflated, sensible, surface qualities and effects. But his instrumental empiricism is not an appreciation of technological progress at large. Instead, it celebrates the ability *to "see"*. In this way, an 'armed eye' (or what Hooke calls an 'artificial organ') can mediate between the surface and its constituents. Leibniz's blazoning of the

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927 Cohen and Wakefield, *Protogaea*, xxxiii.
928 Glacken, *Traces on the Rhodian Shore*, 506.
929 For Kepler's revolution in optics, and how the instrument replaced the eye, see Gal and Chen-Morris, *Baroque Science*, Part I: Observation (especially Chapters 1 and 3).
930 Gottfried Wilhelm Leibniz, and Onno Klopp (ed), Die *Werke von Leibniz*, Volume 6 (Hannover: Klindworth's Verlag, 1864–1884), 214, cited in Glacken, *Traces on the Rhodian Shore*, 507. Rudolf Walter Meyer, and J P Stern (trans), *Leibnitz and the Seventeenth-Century Revolution*, (Glasgow: Bowes and Bowes, 1952 [Hamburg, 1948]), 123. Digitised by the Internet Archive in 2011, at https://archive.org/details/leibnitzseventee00meye. Re-accessed 24/12/22.

benefits of instrumental observation sounds like Hooke's on '*the adding of* artificial Organs *to the* natural' in the preface to the *Micrographia*, which Leibniz longed to read and finally got his hands on in 1678, thirteen long years after its publication:[931]

> *By the means of* Telescopes, *there is nothing so* far distant *but may be represented to our view; and by the help of* Microscopes, *there is nothing so* small, *as to escape our inquiry; hence there is a new visible World discovered to the understanding. … By this the Earth it self, which lyes so neer us, under our feet, shews quite a new thing to us …*[932]

Several scholars have argued that Leibniz assumes a pre-established order and harmony in the universe because of his belief that God created 'the best possible of all worlds'.[933] Yet for Leibniz, this idea comes not from an axiom upon which to make the world, but from what he describes as active *seeing* (instead of imagining, which is a passive looking).[934] Moreover, the instrument not only enables him to see this way but also trains his naked eye to employ the precepts of the telescope or microscope. For example, on the apparently chaotic eruptions of Vesuvius, Leibniz argues, as if *seeing* through a microscope, that

> whoever would have sensitive organs penetrating enough to perceive the small parts of things would find everything organized, and if he could continually augment his penetration to the degree needed, he would always see new organs which were imperceptible previously.[935]

This conjecture, laid on foundations of instrumental empiricism, obviously applies to Leibniz's metaphysics, too: perception is a 'passing condition' that represents variety in the monad; and '*activity* is attributed to the monad in so

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931 Hooke, *Micrographia*, *Preface,* unpaginated. Wilson, *The Invisible World*, 88, 207.
932 Hooke, *Micrographia*, *Preface,* unpaginated.
933 For example, see Rossi, *The Dark Abyss of Time*, 52–55; Ariew, 'Leibniz and the Petrifying Virtue of the Place', 52–53; Glacken, *Traces on the Rhodian Shore*, 477–478; Wilson, *The Invisible World,* 206.
934 For Galileo's hard instrumental empiricism, see Gal and Chen-Morris, *Baroque Science,* Chapter 3. For Hooke, see Hodoba Eric, *The Capture of Spring*.
935 Gottfried Wilhelm Leibniz, and Philip Wiener (ed), *Leibniz Selections* (New York, USA: Charles Scribner's Sons, 1951), 200.

far as it has *distinct perceptions*, and *passivity* in so far as it has *confused perceptions*'.[936] As shown, this novel way to see translates to Leibniz's observations of fossils: when he sees *as* an artificial instrument, he frees himself of imagination's games, which look for familiar images – 'the pope's tiara, of Luther, and all sorts of other shapes etched in the stone of Eisleben'.[937]

Likewise, as shown, Hooke replaces the eye with the microscope as a means to '*impartially examine* the *true appearances* of them [fossils]' by revealing 'Characteristicks'; recall, this is his term for a collection of features used for the identification of these new physical objects of the new science – such as the characteristic pores observed in petrified wood.[938] However, as shown, the characteristic features of fossils cannot be counterfeited by art: even if the outer form of a fossil can be mimicked by, for example, goldsmiths, fossils contain an internal depository of historical authenticity – of 'marks' made by mechanisms of petrifaction over deep time, of essential qualities that make them fossils. Just as Hooke's inversion of Plot's use of antiquities as objects of natural history separates objects of art from objects of nature, his defence of the inherent historicity of fossils is supposed to distinguish them from coins and other antiquities of civil history, which 'may be counterfeited … as may also Books, Manuscripts and Inscriptions, as all the Learned are now sufficiently satisfied, has often been actually practiced'. This may seem a strange move for Hooke, perhaps the most radical apologist for artificial instruments alongside Galileo, because it is inconsistent with his claims on their importance and power.

In the *Micrographia*, Hooke dreams of building an ideal instrument powerful enough to reduce nature to the rudeness of art: 'were we able *practically* to make *Microscopes* according to the theory of them', then we could reduce, for example, even nature's sharpest points to '*broad*, *blunt* and very *irregular*' needles.[939] So, unlike Leibniz, for Hooke the instrument increases

[936] Gottfried Wilhelm Leibniz, and R Latta (trans), *Monadology*, (London, England: Oxford University Press, 1898 [1720]), § 14, § 49. Italics added.
[937] Leibniz, *Protogaea*, 53.
[938] Hooke, *Discourse of Earthquakes*, 411. See also, Hooke, *Discourse of Earthquakes*, 397.
[939] Hooke, *Micrographia*, 2; Hodoba Eric, *The Capture of Spring*, 67.

disorder. But showing that nature is as rough and approximate as art is not the same as counterfeiting it superficially, and Hooke's insistence that characteristics cannot be counterfeited by art is part of his answer to the problem that Leibniz voices to Burnet of Kemnay: it is another way to ensure that history has the same 'science of proof' as natural philosophy. To claim like Leibniz that one can learn how nature fashions a fossil by studying the art of goldsmiths is to risk the implication that nature's history can be counterfeited – a problem commonly faced by antiquaries and associated with objects of civil history. According to Rappaport, unlike written histories from trusted sources, inscriptions on coins, monuments and so on could 'exaggerate the virtues of a ruler' (which means they could also omit vices). The Dutch antiquary Gisbert Cuyper pointed out that

> Certainly the study of medals is very useful, but it will do more harm than good if we allow ourselves to ignore the testimony of the best historians, and if we multiply the number of emperors every time we find a variation in their features or facial expressions.[940]

By multiplying the 'number of emperors' without necessity, Cuyper means that antiquaries and historians risk blunting Occam's razor, which, you'll recall, Hooke accused the *lapides sui generis* side of doing.

We examined the importance of the metaphor of fossils as nature's antiquities to Hooke's argument in Chapter 5; and Steno's use of it in Chapter 7; Leibniz's is similar, though not nearly as explicitly voiced as Hooke's, because it need not be. Hooke works hard to convince his readers and audience that fossils are nature's coins, but if this is taken literally, they come with the same dangers as minted ones. That is, if the danger dominates the metaphor, its intended transfer of meaning on account of some 'inherent resemblance' or 'similarity', to borrow from John of Salisbury once more, is diminished or even

[940] Gisbert Cuyper, *Letter to Huet, 13 February 1716*, in Alfred Lombard, *L'abbé Du bos, un initiateur de la pensée modern, 1670–1742* (Paris: Paris Hachette, 1913), 37–38. At the Internet Archive, https://archive.org/details/labbdubosunini00lombuoft/mode/2up, re-accessed 24/12/22. I am indebted to Rhoda Rappaport for this reference, for she cited Lombard's work: see also Rappaport, *When Geologists Were Historians*, 68–69.

lost.[941] In bolstering his intended meaning, Hooke undermines it. These are not problems that either he or Leibniz solve to their satisfaction, though Hooke's exasperation and frustration with natural philosophers who place no limits on doubt is palpable when, comparing a fossil to a piece of gold (Chapter 3), he states that if all possible empirical examinations answer 'to the properties of Gold', concluding otherwise is to do so 'without Reason'. One must be able to 'conclude and acquiesce' from exhaustive experiments and observations, 'otherwise', according to Hooke, 'there can be nothing at all known that it is this or that Body, and then there is no end of all further Inquiry or Experiment'.[942] Finally, 'assurance sufficient … ought not to be denied … without as evident a manifestation to the contrary'.[943] Although the metaphor is a visual one, and although Hooke highlights naked-eye and instrumental observation, his fossil objects are meant to be 'read' as written histories, and problematising the coin metaphor reveals interesting tensions in the incomplete metamorphosis from the so-called "bookish culture" of the scholastics in which texts mediate knowledge to the instrument-mediated empirical prowess of the new science. This incomplete metamorphosis is Leibniz's workaround to history's 'science of proof'.

However, as James Bono argued, the scholastic 'pursuit of knowledge and search for truths' via the 'mediation of texts' was not culled by one fell swoop of the new science, nor was it simply a turn 'from nature emblematized to nature laid bare – in short, from narrative to description'.[944] Instead, hermeneutical techniques and literary embellishment were incorporated into new practices of experimental observation of physical evidence, and vice versa, despite the new science 'rhetorically presenting itself as no more than a turn towards "things" … to mask its origins in language and narrative'.[945] Amongst tensions operating on account of the overlap of these two worldviews, and traditions of knowledge, the turn away from a metaphysics of

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941 John of Salisbury, *Metalogicon*, Book III, 182; Book I, 68.
942 Hooke, *Discourse of Earthquakes*, 332.
943 Hooke, *Discourse of Earthquakes*, 333.
944 Bono, *The Word of God and the Languages of Man*, 3, 272.
945 Bono, *The Word of God and the Languages of Man*, 273–274.

signs and signatures, and the re-turn to the ancient idea of fossils as re-presentations and imprints, of ideas in things (a turn of phrase I borrow from the 20th-century poet William Carlos Williams),[946] was a necessary move for the making-of a history of the earth *from* the earth. In attempting to present the unpresentable, and to render the strange as familiar, fossils needed to be anchored to a comprehensible image of reality – the text – especially because they were to be read differently with new instruments. Metaphor, as a device of knowledge transference and transformation, 'often regarded as opposite in principle to the precise, literal language of scientific discourse', became a tool for such 'exchanges', forging novel ways to articulate thinking, and therefore discourse, as well as meanings and practices, by borrowing from old ones.[947] Only by assailing and appropriating the ingrained idea of correspondences, by presenting fossils as nature's documents, could one attempt to change the meaning of the 'book of nature' idiom altogether, as I showed also with Hooke's inversion of Plot's use of antiquities for natural history. Put another way, conquering the *things* of the culture of correspondences (signs and signatures, woven into the microcosm-macrocosm world tapestry upon which traditional alchemy depends), that Leibniz turned his back on, required reshuffling the fragments of this culture's ruins into a new historical text on nature – not free of the old contradictions, but producing new ones.

The concept of the two books of God (also known as the two revelations or two lights doctrine) – the scriptures and the book of nature – was tropified in the Middle Ages.[948] In the words of Dugdale's friend and confidant Browne,

> there are two Bookes from whence [sic] I collect my Divinity; besides the written one of God, another of His servant nature; that universall and publike Manuscript, that lies expans'd unto the eyes of all; those that never saw [H]im in the one, have discovered [Hi]m in the other[.][949]

[946] William Carlos Williams, *Paterson*, Book I (Singapore: Penguin Books, 1963), 6. At the Internet Archive, at https://archive.org/details/PatersonWCW/page/n3/mode/2up. Re-accessed 24/12/22.
[947] Bono, *The Word of God and the Languages of Man*, 10, 11.
[948] Ferber, *A Dictionary of Literary Symbols*, 33.
[949] Thomas Browne, *Religio Medici*, 30. See also Ferber, *A Dictionary of Literary Symbols*, 33.

Browne explains that the book of nature 'was the Scripture and Theologie of the Heathens'. Upon comparing them to the 'Children of Israel' (thus Christian theology) and the 'written' book 'of God', Browne claims that 'the ordinary effect of nature wrought more admiration in them [heathens], than in the other all [H]is miracles'. Although Browne hastens to add that one must be on intimate terms with both books, he nevertheless concludes that

> surely the Heathens knew better how to joine and read these mysticall Letters, than wee Christians, who cast a more carelesse eye on these common Hieroglyphicks, and disdain to suck Divinity from the flowers of Nature.[950]

As discussed, on the inversion of material and divine, around about two decades later, Hooke placed common things, and simplicity in thought and experimental design, on a pedestal in the *Micrographia*; and in his *Discourse*, he repeated Browne's reproach on disdaining to draw divinity from things 'common':

> Men do generally too much slight and pass over without regard these … Hieroglphick Characters of preceding Transactions in the like duration or Transactions of the Body of the Earth.[951]

In fact, Hooke had Browne's *Religio Medici* in his library, from which the above quote is taken, as well as his other works.[952] With his polyhistor study of Earth – namely, historiographical practice, and natural philosophy, as both the study of ancient texts, and what Svetlana Alpers dubbed the 'art of describing'[953] in contrast to narrating – Hooke wields the metaphor of 'common Hieroglyphicks' to argue that fossils are 'written in a more legible Character than the Hieroglyphicks of the ancient Egyptians, and on more lasting Monuments than those of their vast Pyramids and Obelisks'. Nature's hieroglyphics are 'the

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950 Browne, *Religio Medici*, 30–31.

951 Hooke, *Discourse of Earthquakes*, 411.

952 Hooke's Book database project: Felicity Henderson, Yelda Nasifoglue and Will Poole (eds), 'Hooke's Books Database | Robert Hooke's Books', 2018, at http://www.hookesbooks.com/hookes-books-database/.

953 For further explanation, see Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century* (Chicago: The University of Chicago Press, 1983), xxv.

greatest and most lasting Monuments of Antiquity, which, in all probability, will far antidate all the most ancient Monuments of the World … and will afford more information in Natural History, than those other put altogether will in Civil,' because the 'great transactions of the Alterations, Formations, or Dispositions of the Superficial Parts of the Earth into the Constitution and Shape which we now find them to have, *preceded the Invention of Writing*'. Hence, Hooke invents a new system of writing capable of crafting stories on nature's changes by turning history into an object of the new science. The design, and the attempt to erase "stones" with "snails", is his: '*I* have designed 15 several sorts of Snail *rather than* Snake-stones'.[954] Fossils, he argues, emphasising their physicality down to the microscopic details, spell the words in a historical text that he can read, having identified the marks and characteristics by examining and representing them with instrument-mediated descriptions and depictions.

Just as '*the Earth it self*', in Hooke's words, '*shews quite a new thing to us*' because of new 'artificial Organs' such as the microscope, wells sunk into the earth provide optical instrument, an artificial aperture, which lets Ramazzini and Leibniz dig beneath surface appearances and expose the strata. Wells may not have seemed an obvious instrument till now, because not all metaphors are as explicit as Hooke's. Because of Leibniz's anxieties about looking versus seeing, and his complex relationship with Kircher and Becher's signatures, throughout the *Protogaea*, Leibniz subverts the use of poetic devices in historiography with lists of descriptions. Consider the following excerpt from a long account of layers revealed by a well dug in Amsterdam: 'seven feet of garden earth, nine of peat, nine of clay, eight of sand, four of earth … ten feet of sand upon which the houses there are anchored … four of sand mixed with seashells'. Stripped of tropes and even sensual details, Leibniz lists only what and how much. When he does add adjectives, they are carefully chosen to actively arouse the senses – especially olfaction – to enhance the materiality of his evidence, and to control the imagination. Taking interest in a well in 'Rosdorf near Göttingen', because it had to be dug to 'a greater depth'

[954] Hooke, *Discourse of Earthquakes*, 281. Italics added.

(beyond the initial sixteen feet) after water had 'abandoned the surface', Leibniz relates an account given by an unnamed pastor, 'a not unlearned man', of the strata exposed. 'There the diggers again encountered a *black stinking soil*, eight feet thick, composed of *rotten* leaves, stalks, grass, root threads, and many shells'.[955] The layer under the one with shells is '*slimy*'.[956] Nevertheless, the way that Leibniz describes the strata as a whole as well as the details of their contents embodies the book metaphor. From a literary or poetic perspective, Leibniz's layers are nature's documents: he transfers the old practice of history as a study of ancient texts to nature's ancient layers, using them in place of pages.

[955] Leibniz, *Protogaea*, 129. Italics added.
[956] Leibniz, *Protogaea*, 131. Italics added.

# CHAPTER 10: CONCLUSION

Many years later, Charles Darwin, penning *On the Origin of Species*, would borrow 'Lyell's metaphor' of strata as pages and text as fossils: this new "book of nature" had come to dominate different visualities of Earth and its history.

> For my part, following out Lyell's metaphor, I look at the natural geological record, as a history of the world imperfectly kept, and written in a changing dialect; of this history we possess the last volume alone, relating only to two or three countries. Of this volume, only here and there a short chapter has been preserved; and of each page, only here and there a few lines.[957]

Lyell had to defend the book's strengths as an analogy for empirical inquiry,[958] but in Darwin's hands, its missing pages proved just as important and interesting. Without them, Darwin could argue that even if the fossil record is too incomplete to provide evidence for his ideas on species and evolution, it is also too incomplete to provide strong evidence against his theory.[959] The metaphor itself was subject to hermeneutical scrutiny and change, and that Darwin and Lyell share the new book of nature with Leibniz, Ramazzini, Steno, Hooke, Dugdale, and others means that they are partaking of this tradition. Even Ramazzini, a contemporary of Leibniz who shares his same subject matter, underscores different passages of nature's book.

Unlike Ramazzini, Leibniz directs equal attention to the man-made strata exposed by the wells: at 'a depth of ten feet, they encounter the debris of the old city, unearthing the paving stones of forgotten avenues and other vestiges of antiquity. So far did the city rise on hauled earth and its own ruins'. Then, after another layer of earth, appears 'debris again twelve feet lower, as if the city had been destroyed more than once'. Leibniz adds later that 'Este in

[957] Charles Darwin, *On the Origin of Species: Facsimile of the First Edition* (London: John Murray, Albermale Street, 1859), 310–311.
[958] Taub, 'Evolutionary Ideas and 'Empirical' Methods: The Analogy between Language and Species in Works by Lyell and Schleicher', 171-172.
[959] Gene Hunt, 'Evolution in Fossil Lineages: Palaeontology and *The Origin of Species*', *The American Naturalist*, Vol. 176 (2010): S61-S76.

Lombardy recalls an analogous ruin of earths'.[960] Because of his belief that even the disorder of these ruins of antiquity is ordered, their disorder is only apparent, just as the cause of their ruin resulted from mixed causes instead of one (perhaps war and nature), as the sometimes gradual, sometimes sudden and violent formation of the physical layers attests: upon a foundation of nature's layers 'was built the old city, which the barbarian invasions destroyed; after that, one perceives how rains and floods heaped earth onto the ruins'.[961] And so on. By juxtaposing the differences between the alternating and apparently pell-mell layers of natural and civil history – of nature stopped by cities, of cities and human enterprise ruined – Leibniz unifies them into a narrative.

Of the layers in between the remains of cities, Leibniz concentrates on those containing subterraneous trees, petrified wood and earthy matter 'crammed with many shells'.[962] Despite the different historical conditions that make up each layer, which affect Ramazzini with a sense of estrangement, Leibniz has little difficulty in linking fossils to the beings they once were: art divulges how they were metamorphosed; and now layers represent historicities with which he can situate them. Similarly in Rosdorf, Leibniz finds a layer full of subterraneous firs, and comparing it to the present appearance of the land, which 'has no fir trees', creates a historical situation, concluding that 'So much has the nature of the place changed'.[963] Like Dugdale, who in England noted that 'the bodies' of such trees were found positioned 'for the most part North West from the roots', Leibniz considers it 'remarkable' that in 'Lüneburg and elsewhere' (Bruges, Frisia and the province of Groningen), 'most of them lie in the same position, with the roots pointed between north and west, and the tips pointed between east and south'.[964] And just as Dugdale conjectured that a whopping wave had swept catastrophically inland, Leibniz states that the oddly flattened trees are

[960] Leibniz, *Protogaea*, 129, 131.
[961] Leibniz, *Protogaea*, 127.
[962] Leibniz, *Protogaea*, 131.
[963] Leibniz, *Protogaea*, 131.
[964] Leibniz, *Protogaea*, 139.

> why learned men believe that *in a time before all reported history*, the boiling ocean, raging from the northeastern and northwestern winds that still attack these coasts today, burst onto the land with great force. And that one assault covered all of lower Germany with debris.[965]

Petrified trees together with 'shells' provide enough evidence for Leibniz to write an episode of actual Earth history. Back to his description of the Amsterdam well, which began with a list of measurements that could be counted and categorised into occurrences of similar strata – 'peat occurred once, earth five times, clay also five times, sand more than six times, and shells once' – he claims, first, that there was probably 'once a seafloor where shells now lie, at a depth of more than one hundred feet. Repeated floods and catastrophes have thrown all the layers of clay and sand upon this floor, while the deposits of earth arose during the intervening periods'. Second, linking the layer of shells to the flattened trees, Leibniz continues the story, personifying 'the sea':

> The sea, driven back, retreated for a time. But ultimately insisting on its right, the sea once again burst the dams, flooding the lands and flattening the forests, whose ruins are now revealed by the diggers. [966]

Now that Leibniz is secure in his own version of writing the book of nature, he can afford to adorn it with literary devices. It is crucial that nature's 'ruins are now revealed *by the diggers*', for this adds further credence to Leibniz's epistemology, his insistence that we know by art not nature, which is only nature on a human-sized scale, mediated by instruments. Since the strata are physically connected, whether by gradual sedimentation or 'by a strange and most violent impulse' like an earthquake or volcano, as Leibniz would similarly conclude when arguing for the interconnectedness of matter in his *Monadology*, one 'can discover in the present what is distant both as regards space and as regards time'.[967] Again: causally hence historically. Thus, 'For us,

[965] Leibniz, *Protogaea*, 139. Italics added.
[966] Leibniz, *Protogaea*, 141.
[967] Leibniz, *Protogaea*, 127; Leibniz, *Monadology*, § 61.

nature stands in place of history. But our written history repays nature's grace, so that her brilliant works, which still lie open before us, will not be ignored by posterity.'[968]

Leibniz's optimism was an outcome of seventeenth-century instrument-mediated observation, imagination, and representation, which figuratively lengthened the human life span by allowing us to peer deeply into all things – including the earth's past, either with or as-if-with new optical instruments. The new seventeenth-century understanding of history had its inception with Bacon's edict to historicise both alchemical language and practice during the poetry versus history controversy. The edict was enacted by Hooke putting it into practice with his studies of fossils and earthquakes, his passionate preference for the common over the rare, and a long and vehement defence of his historicity of the earth from the earth itself. These ideas and practices were imported to the Continent, and thus have inevitably led us to closing *Metamorphoses* with Leibniz's historical thought and work, because here we can see the culmination of everything discussed thus far, as well as hints of future historiography. This new way of thinking about, doing, and writing history complemented the rise of the new science, and its culture. Without launching the earthly into the realm of the divine like Kepler and Galileo, and without dragging the divine back down to earth like Ray, Burnet, and other physico-theologians, a historical investigation of nature would have been hardly possible, for divinity, from the Ancient Greeks to the eighteenth century, was almost always associated with stasis, not change.

Unlike the static explanation of fossils as nature's games, the idea that fossils are either the remains of organisms or their imprints fashioned a new causal and dynamic philosophy of history, even if its practitioners were seemingly few. Yet the new historiography was a tapestry woven from a warp and weft ancient and modern, as much as it was of a shared shift in observation and imagination. It was also an experience of history particular to the seventeenth century with its instrument-mediated vision, and novel

[968] Leibniz, *Protogaea*, 141.

investigative methods.

But divinity was never far behind. Physico-theologians like Ray, excited by the benefits but also apprehensive of the dangers in the work of radical antiquaries, experimentalists, and natural philosophers such as Dugdale and Hooke, still applied difficult compromises to ensure that a study of nature and its history remained – perhaps more so than ever – a study of God and his creation. On the other hand, the work undertaken by Hooke, Steno, and others of the organic origin persuasion was a genuine and sincere attempt to restore Earth to its Edenic state. It was a genuine attempt at artificial apotheosis. This was also the ambition behind Bacon's sanitisation of alchemy: to pave the path to 'a restitution and reinvesting … to man of the sovereignty and power (for whensoever he shall be able to call the creatures by their true names he shall again command them) which he had in his first state of creation'.[969]

*Figure 11: Visitors inspecting the meticulously ordered wonder cabinet of the Vincent museum, in Levinus Vincent,* Elenchus *(1719). A table of fossils sits on display on the lower-right.*

[969] Francis Bacon, and James Spedding (ed), et al., *Valerius Terminus of the Interpretation of Nature* (1603), in *The Works of Francis Bacon*, Vol. III (Stuttgart: Friedrich Frommann, 1963 [1859]),

Hooke's desire to call fossils by their true names, in identifying what they once were, made Bacon's idea a reality. 'By the addition of such artificial Instruments and methods, there may be … a reparation made for the mischiefs, and imperfection, mankind has drawn upon it self'.[970]

Francken's painting *The Collector's Cabinet* displayed the mixture of early modern historicities but also exuded Bacon's and Hooke's enthusiasm for the intellectual currency that such a place of collected potential could provide. Another cabinet, closer to the other end of the century, wonderfully presents what such enthusiasm became as well as how these historicities were separated and ordered. Figures 11 and 12 respectively show etchings of and from one of the greatest wonder cabinets of all: the vast, the varied *Wondertooneel der natuur* of Levinus Vincent (1658–1727).[971] Unlike Francken's cabinet, Vincent's has a place for everything and

*Figure 12: A collection of fossils stored in cabinets 11 and 12, in Levinus Vincent,* Elenchus *(1719).*

222.

[970] Hooke, *Micrographia*, Preface, unpaginated.

[971] William B Ashworth, *Scientist of the Day – Levinus Vincent*, at Linda Hall Library. https://www.lindahall.org/about/news/scientist-of-the-day/levinus-vincent. Re-accessed

everything is in its place – including the fossils collected in cabinets 11 and 12 (Figure 12), and on public display in the lower-right side of Figure 11.[972] Gone is the heterogeneous hotchpotch of sacred, civil, and natural histories. Instead, here we find a history of the earth as ordered as Steno's strata. In this respect, and juxtaposed with Francken's earlier cabinet, Vincent's cabinet represents the changes that were still occurring to seventeenth-century ideas on history, specifically the earth's, but also changes to the experience of this history and our place in it.

Hooke, Steno, Burnet, Dugdale, Ramazzini, and Leibniz broke from traditional history in idiosyncratic yet overlapping ways. The shared idea about what a fossil is fostered a shift in visuality belonging to the seventeenth century with its instrument-mediated vision, and novel investigative methods; but it also represented their new attitudes to history, for interest in fossils was not only about phenomena. Rather, by amalgamating new ways of observing and imagining the earth with ancient wisdom, alchemical ideas, and humanist textual practices, these Earth historians fashioned historiographical approaches that could scarcely have been imagined a century before. Leibniz's struggle to make a history reinforced by a seventeenth-century 'science of proof'[973], by mixing helpings of the work of Burnet, Ramazzini, and others into his own ideas handed new tools to eighteenth-century historians, not only tools for doing and thinking about Earth history but also tools for witnessing and understanding its metamorphoses.

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[972] William B Ashworth, *Scientist of the Day – Levinus Vincent*, at Linda Hall Library. https://www.lindahall.org/about/news/scientist-of-the-day/levinus-vincent. Re-accessed 24/12/22.

[973] Leibniz wrote on the need for scientific evidence to verify historical facts in a letter to Thomas Burnet of Kemnay – not to be confused with the Thomas Burnet discussed here: Leibniz, *Die philosophischen Schriften …*, Volume 3, 193–194: 'Mais la Philosophie pratique est fondée sur la véritable Topique ou Dialectique, c'est a dire, sur l'art d'estimer les degres des probations … et peuvent servir de commencement pour former la science des preuves, propre a verifier les faits historiques …' (Transcribed by me.)

# APPENDIX 1

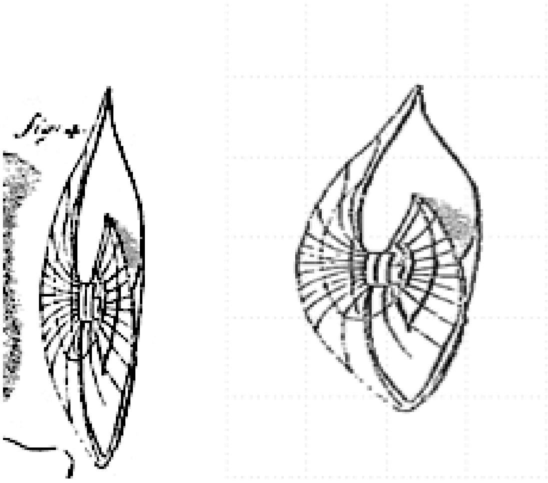

*Figure 13: Undoing the anamorphosis of 'fig 4' reveals a regular shell shape.*

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